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# PUBLIC SCHOOL CHEMISTRY.

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THE PUBLIC SCHOOL  
CHEMISTRY,

BEING, AT ONCE, A  
SYLLABUS FOR THE MASTER,  
AND AN  
ABSTRACT FOR THE BOY.

BY

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*Second Edition—Revised, Corrected, and Enlarged.*

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## PREFACE.

MOST subjects have books which do not attempt to teach but are to teach from. Hitherto such books have been wanting in Chemistry. The great feature in such books should be a course including all important points, and clear, exact, and concise statements of difficult portions. Most books are diffuse and intangible to boys reading them. They require analysis and abstraction—the separation of facts and principles from theories and details. This book proposes to be just the abstract that boys require, and the sort of syllabus that schoolmasters generally prepare. After the class lectures and demonstrations are over, the boy that has this book will find that he has a very precise lesson to learn, and not merely a chapter to read.

Details of manipulation, and diagrams of apparatus, find no place in this book. What need is there for them when all practicable experiments have been seen and all details heard? Excellent material for out of school work will be the drawing of apparatus, and the writing out of experimental details. Habits of attentive observation will thus be encouraged, while, to aid the memory, notes may be taken. To facilitate note-taking, the text of the book is printed only on one side. The other side is left for notes and sketches. Numerical exercises will afford additional material for work in or out of school. These can be given to any extent quite readily by any teacher. Typical examples are worked out in the book.

It is not necessary that the book should be used in the order in which it is arranged. If thought advisable, an elementary course of Hydrogen, Oxygen, Water, Nitrogen, Air, and the Oxides of Carbon may be taken first. Still, the arrangement adopted is the order which the author has, after ten years' experience, found most satisfactory. Many useful, instructive and attractive experiments can be devised to illustrate an elementary exposition of Theoretical Chemistry, without at once plunging into Hydrogen and Oxygen.

This is no "cram book" in the bad sense of that expression. It is not intended to supplant the teacher, but to supplement him. No pictorial illustrations replace experiments. The book is an honest effort to help the diligent to learn what the teacher demonstrates and expounds.

My obligations to my colleague, Mr. H. T. Lilley, M.A., of Balliol College, Oxford, Assistant Science Master at Portsmouth Grammar School, are very great. Since the idea of printing the "Syllabus" was conceived, I have had the great advantage of his constant advice and assistance.

It was hoped that this second and enlarged edition would be absolutely free from misprints. I am, however, indebted to my pupil Mr. H. B. Pollard, Science Scholar of Christ Church, Oxford, for reading the proof-sheets and compiling the list of errata.

*Grammar School, Portsmouth,*  
*March 25th, 1886.*



## ERRATA.

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*Before using this book let the following corrections be made :—*

- p. 13, l. 8, *for* 14 read 28.  
p. 63, l. 9, *for*  $2 + 1$  read  $2 \times 1$ .  
p. 85, l. 24, *for*  $2H_2$  read  $H_2$ .  
p. 87, l. 13, *for* combustion read combination.  
p. 95, l. 26, *for*  $NaSO_4$  read  $NaHSO_4$ .  
p. 97, l. 23, *for* Iodide read Chromate.  
p. 99, l. 36, *for* 2·8 read 97·2.  
p. 101, l. 34, *for* the equation read  $2KBrO_3 = 2KBr + 3O_2$   
p. 117, l. 17, *for*  $O_2$  read  $3O_2$ .  
p. 123, l. 27, *for*  $2HPO_4$  read  $2H_3PO_4$ .  
p. 129, l. 4, *for* Oxygen read Hydrogen.  
p. 133, l. 6, *for*  $4H_2$  read  $4H_2O_2$ .  
p. 133, l. 8, *for*  $BaO_2$  read  $BaO$ .  
p. 133, l. 14, *for* Ag read  $Ag_2$ .  
p. 137, l. 28, *for*  $Ca(ClO_2)_2$  read  $Ca(ClO)_2$ .  
p. 139, l. 22, *for*  $HClO_2$  read  $2HClO_2$ .  
p. 151, l. 3, *for*  $SbS_3$  read  $Sb_2S_3$ .  
p. 163, l. 30, in the equation read  $Na_2S_2O_4 = Ag_2S_2O_3$ , &c.  
p. 185, l. 24, in the equation *for*  $P_3O_5$  and  $N_2O_3$  read  $P_2O_5$  and  $N_2O_5$ .  
p. 187, l. 29, *for*  $NaS_2O_4$  read  $Na_2SO_4$ .  
p. 205, l. 20, *for*  $H_2PO_4$  read  $H_3PO_4$ .  
p. 111, *for* line 32, read—But an atom of Calcium weighing 40 is the equivalent of 2 atoms of Hydrogen,



## Introductory.

1—Chemistry investigates the constitution of bodies. The Chemist ascertains the kinds of matter of which bodies are composed, and also the conditions under which matter can be decomposed, combined, or re-arranged when in combination.

2—If we take a piece of Granite rock, a superficial observation will show that it consists of three distinct Minerals—Quartz, Felspar and Mica. These Minerals are held together by a force that is called *cohesion*. The investigation of this force belongs to the Physicist, and not to the Chemist.

Again, any of the three Minerals may be broken up and powdered down into exceedingly minute portions, each of which is, however, only Quartz, or Felspar, or Mica very finely divided. Here again the force overcome is *cohesion*, and we are still in the domain of the Physicist. The limit of his work is sub-division.

But, any of these Minerals can be resolved into altogether new bodies, *out* of which the Mineral is composed. This resolution is the Chemist's work. The Physicist overcomes cohesion, breaks the rock up into Minerals, breaks the Minerals into minute particles, and then the Chemist resolves the Mineral into elements. Rocks are composed of Minerals. Minerals are composed of Elements.

3—Cohesion must be carefully distinguished from Chemical Combination.

(1) Cohesion unites particles together without causing any change in their physical properties. Quartz is obviously Quartz though united to Mica.

(2) Cohesion holds together similar particles to make up large masses of the same substance.

(3) Cohesion is manifested strongly in solids, feebly in liquids, and not at all in perfect gases. The three states of matter—solid, liquid, and gaseous—are owing to cohesion





## Elements.

1.—*Definition*—An element is a body which, by the means now at command, cannot be resolved or broken up into anything else. All known matter is made up of about seventy such elements.

2—The following is a table of thirty-seven of the most important elements, with the symbols by which they are designated in Chemical Notation :—

Aluminium	Al	Chlorine	Cl	Magnesium	Mg	Silicon	Si
Antimony	Sb	Chromium	Cr	Manganese	Mn	Silver	Ag
Arsenic	As	Cobalt	Co	Mercury	Hg	Sodium	Na
Barium	Ba	Copper	Cu	Nickel	Ni	Sulphur	S
Bismuth	Bi	Fluorine	F	Nitrogen	N	Strontium	Sr
Boron	B	Gold	Au	Oxygen	O	Tin	Sn
Bromine	Br	Hydrogen	H	Palladium	Pd	Zinc	Zn
Cadmium	Cd	Iodine	I	Platinum	Pt		
Calcium	Ca	Iron	Fe	Phosphorus	P		
Carbon	C	Lead	Pb	Potassium	K		

3—Of this number the great majority are rare. About 98 per cent. of the earth's crust consists of Silicon, Aluminum, Calcium, Magnesium, Potassium, Sodium, Iron, and Carbon, combined with Oxygen.

4—The number of the elements is not certain. Matter containing elements hitherto unknown is from time to time discovered. Progress in analytical methods may show that certain of the now so-called elements are really compounds of other elements at present known or unknown. Better observation may show that some elements are really only physical modifications of other elements. It has been suggested (and not without reason) that there are but three primitive elements, and of these three all other so-called elements are composed. These primitive elements are Carbon, Hydrogen, and *Ether*?

5—Each of the elements can be made to combine with certain other elements. Not every conceivable combination is possible. Chemistry investigates what elements combine together, and under what conditions they will form each combination.



## Characteristics of Chemical Combination.

1—Elements which have the strongest tendency to combine have opposite electrical properties.

2—The new compound formed is essentially unlike its constituents.

3—A Thermal change, definite in amount, always accompanies Chemical combination.

4—Elements combine in definite proportions by weight.

5—The new compound cannot generally be broken up by such mechanical means as solution or diffusion.

6—Chemical action is only a re-arrangement of matter, and never the destruction of matter. No matter is ever lost.

## Causes tending to modify Chemical Action.

1—*Cohesion* resists Chemical change. Solids rarely react. Bodies in fusion or solution react readily. Gases combine often with explosive violence.

2—*Heat* by diminishing cohesion favours Chemical change. It augments the spatial intervals between the ultimate particles of bodies, and also increases the agitation of these particles amongst themselves. This increase of the spatial intervals may end in decomposition or dissociation. This agitation of the particles facilitates that contact without which Chemical combination is impossible. *Corpus non agit in alterum nisi dum in ipsum impingit.*

3—*Light* promotes change, sometimes combination, sometimes decomposition, sometimes re-arrangement.

4—*Electricity* may promote either decomposition or combination according to the conditions of the experiment. Ex.: Ammonia is *decomposed* into Nitrogen and Hydrogen by a series of electric sparks. Hydrogen and Oxygen submitted to a spark *combine* and form water.





5—*Nascent state*—Chemical action between two bodies is induced by the disengagement of one in the presence of the other. This effect is due certainly not to the mere disengagement. There is good reason to believe that it is an electrical phenomenon. Bodies exhibit greater tendency to combine immediately after their liberation from combination.

6—*Catalysis*—Certain bodies such as Aqueous Vapour, Spongy Platinum, induce Chemical change, while the inducing body undergoes no apparent change. Such bodies are called Catalysts.

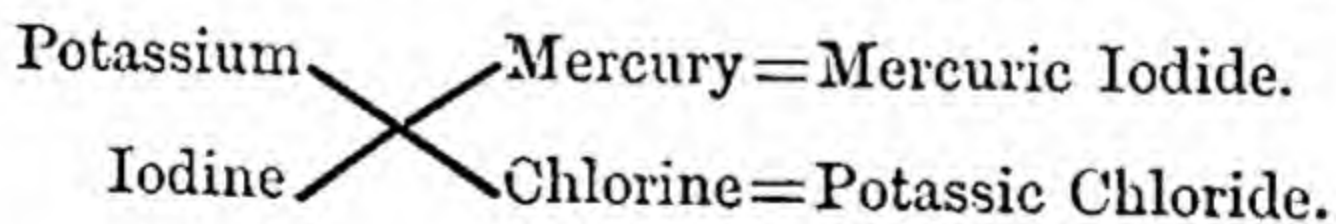
## Chief Modes of Chemical Action.

1—*Analysis* — Mercuric Oxide on heating yields Mercury and Oxygen.

2—*Synthesis*—Iron, when heated with Sulphur, yields Iron Sulphide.

3—*Displacement*—Sodium displaces Hydrogen from Water.

4—*Double decomposition*, or, interchange of partners—Potassium Iodide and Mercuric Chloride, on mixing their solutions, yield Mercuric Iodide and Potassic Chloride.



## Two Fundamental Laws of Chemical Combination.

1—The Law of Constant Composition.  
The same compound always consists of the same elements.



### Experimental Verifications.

1—Ammonium Nitrate, whether obtained by the action of Nitric Acid on a solution of Ammonia, or by the action of Nitric Acid on Ammonium Carbonate, always yields, when heated, the same two gases—Aqueous Vapour and Laughing Gas.

2—Water, whether obtained from natural sources, or by laboratory reactions, always yields, when decomposed by Electricity, the same two gases—Hydrogen and Oxygen.

### 2—Law of Definite Proportion.

The elements in a compound are always present in the same proportion.

### Experimental Verifications.

1—From the same weight of Lead Acetate the same *weight* of Lead is always turned out by Zinc.

2—From the same weight of Sulphuric Acid the same *volume* of Hydrogen is always evolved by the action of Magnesium.

## The Law of Multiple Proportion.

1—The results of Analysis, which revealed the Law of Definite Proportion, were expressed in the form of percentages by weight. Thus 100 parts of Water was said to consist of 11.1 of Hydrogen, and 88.9 of Oxygen.

Similarly the red Oxide of Copper was found to contain 88.8 of Copper, and 11.2 of Oxygen in 100 parts.

The Black Oxide of Copper was found to contain 79.87 of Copper, and 20.13 of Oxygen in 100 parts.

Again one compound of Carbon and Oxygen was found to contain 72.73 of Oxygen and 27.27 of Carbon, while another contained 42.85 of Carbon, and 57.15 of Oxygen.

2—From an examination of such percentages Dalton deduced the Law of Multiple Proportion. The following





example will show how this Law follows from the Law of Definite Proportion :—

If 42·85 of Carbon combines with 57·15 Oxygen,

Then 1 of Carbon combines with  $\frac{57.15}{42.85} = 1.33$  of Oxygen.

And if 27·27 of Carbon combines with 72·73 Oxygen,

Then 1 of Carbon combines with  $\frac{72.73}{27.27} = 2.66$  of Oxygen.

Now,  $1.33 : 2.66 :: 1 : 2$ .

Therefore the quantity of Oxygen combined with the same amount of Carbon in the second of these two compounds is double the quantity in the first. If the first be written CO, the second must be written COO, or CO<sub>2</sub>.

In the same way it may be shewn that the two Copper compounds can be written Cu<sub>2</sub>O and CuO respectively.

3—From an extended investigation of similar cases, the following general Law of Multiple Proportion is deduced.

When an Element unites with another in several proportions, the higher proportions are simple multiples of the lower.

4—It follows from this law that, if a substance be found to contain elements in any proportions other than multiples, by unity or other integer, of their atomic weights, the substance is not a chemical compound. It is only a mixture. Thus air contains Oxygen and Nitrogen in the proportion of 16 of Oxygen to 51·5 of Nitrogen. As 51·5 is not a simple multiple of 14, air is held to be a mixture and not a Chemical compound.

## Law of Reciprocal Proportion.

If two bodies, A and B, each combine with a third body, C, they can only combine with each other in proportions which are measures or multiples of the proportions in which they each combine with C.



Thus Nitrogen and Hydrogen each combine with Oxygen in the proportions shown below :—

	Nitrogen.	Oxygen.
Laughing Gas	28	16
Water	2	16

Nitrogen and Hydrogen combine with each other to form Ammonia in the proportion of 14 of Nitrogen to 6 of Hydrogen. Now 6 is a simple multiple of 2.

## The Atomic Theory.

To explain these Laws Dalton revived the Atomic Theory, and extended it by introducing the idea of quantity. This may be thus stated :—

(1) Matter is made up of minute indivisible particles called atoms.

(2) Atoms of the same elements have the same weight, but atoms of different elements have different weights.

(3) Compounds are formed by the coalition of atoms of elements.

(4) The weight of the atom of any element may be expressed relatively to the weight of any element selected as a unit. Hydrogen is the element chosen for this purpose.

## Evidence for the Atomic Theory.

1—The Porosity of Matter. Examples: (1) The Florentine Experiment. (2) One gas acts as a vacuum to another.

2—That light is propagated only through bodies that are discrete.

3—The phenomena of the dispersion of light are possible only if the body causing dispersion is discrete.





5—The Atomic Theory has not only explained the laws of combination, but, as a working hypothesis, has materially aided the development of Chemistry and Physics.

## Application of Dalton's Principle to Chemical Notation.

(1) Assuming that the weight of Hydrogen in every Hydrogen compound is unity, Dalton drew up a table of what he called Atomic weights. Allowing for experimental errors, the numbers produced by Dalton for a few of the more important elements were the following:—

H	=	1	N	=	4.66
O	=	8	C	=	6

Dalton's numbers, however, are not properly speaking Atomic weights. They are proportional numbers referred to a unit, which is the weight of Hydrogen in each Hydrogen compound. His chosen unit is really a variable quantity.

Dalton's assumption that the amount of Hydrogen in every Hydrogen compound is unity was soon shown to be untrue by Gay Lussac and Avogadro.

## Gay-Lussac's Law of Volumes.

1—In 1805 Gay Lussac's experiments on Gases led to the discovery of the following law:—

Gaseous substances unite in volumes that have some simple ratio.

(1) 1 volume of Hydrogen and 1 volume of Chlorine form 2 volumes of Hydrochloric Acid.

(2) 2 volumes of Hydrogen and 1 volume of Oxygen form 2 volumes of Steam.

(3) 3 volumes of Hydrogen and one of Nitrogen unite to form 2 volumes of Ammonia.



2—An investigation of Volumetric combination reveals also these three laws :—

(1) When the gases combine in equal volumes there is generally no contraction.

(2) When the gases combine in unequal volumes there is generally a contraction.

(3) The resultant contracted volume is generally equal to two units of the volumes that have combined.

3—Gay-Lussac also observed that the weights of equal volumes of the gaseous elements are in the same ratio as their Atomic weights—that is to say, equal volumes contain the same number of atoms. This paved the way for the great Law of Avogadro, by which the Theory of Dalton and the Law of Gay-Lussac were brought into perfect harmony.

## Law of Avogadro.

Equal volumes of different gases contain the same number of Molecules.

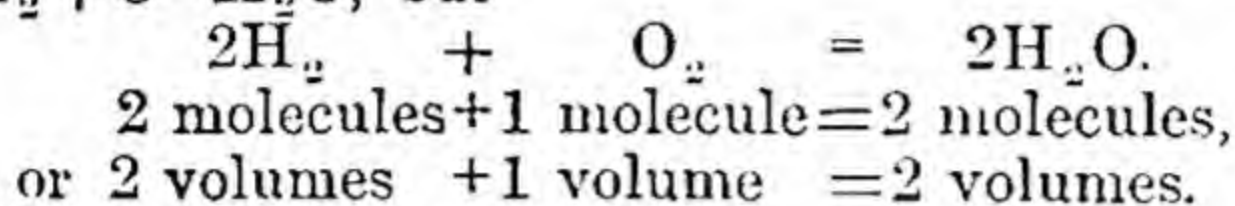
1—Since a volume of Oxygen is 16 times as heavy as a volume of Hydrogen, it follows from Gay-Lussac's theory that if the Atomic weight of Hydrogen be 1, the Atomic weight of Oxygen is 16. Now Oxygen and Hydrogen combine together in the ratio of 8 to 1 by weight, and therefore in the ratio of 16 to 2. We must therefore write Water  $H_2O$ .

2—Although 2 parts by weight of Hydrogen combine with 16 parts by weight of Oxygen to form 18 parts by weight of Water vapour, yet Water vapour is not 18 times as heavy as Hydrogen. It is found to be only 9 times as heavy. To remove this difficulty, Avogadro re-stated Gay-Lussac's Theory thus :—"Equal volumes of different gases contain the same number of *molecules*." The molecules of elementary gases are made up of two atoms of the same kind. The molecule of a compound gas is built up of atoms of different kinds, and whatever be the





number of atoms in it, the molecule always occupies the same space as the two atom molecule of an elementary gas. Reaction is always between molecules. Therefore, in accordance with Avogadro's Theory we must write not  $\text{H}_2 + \text{O} = \text{H}_2\text{O}$ , but



This equation expresses the proportions *by volume*, and also the proportions *by weight*.

Equations should always be written molecularly.

3—On purely dynamical grounds it can be mathematically demonstrated that equal volumes of two gases, at equal temperatures, contain the same number of molecules.

4—Hence it follows that in gases the masses of molecules must be in the same ratio as the densities of the gases. This principle will enable us to establish a system of molecular weights.

The following Table exemplifies the determination of the molecular weights of a few bodies :—

Name of Body	Density compared with air=1	Ratio of Densities	Molecular weights H=2
Hydrogen	·0693		2
Chlorine	2·44	·0693 : 2·44 :: 2 : $w$	$w = 71$
Bromine	5·393	·0693 : 5·393 :: 2 : $x$	$x = 160$
Iodine	8·716	·0693 : 8·716 :: 2 : $y$	$y = 254$
Water	·6227	·0693 : ·6227 :: 2 : $z$	$z = 18$

5—It is only in the *gaseous* state that molecules occupy equal volumes. The density of air with respect to Hydrogen is  $\frac{1}{\cdot 0693} = 14\cdot 4$ .



Remembering this, from gaseous density we can find molecular weight, and from molecular weight we can find gaseous density.

Examples: (1) The density of gas compared with air is 1.1, find its molecular weight.

Density compared with Air  $= 1.1$

∴ " " Hydrogen  $= 1.1 \times 14.4 = 15.84$

And molecular weight  $= 15.84 \times 2 = 31.68$ .

(2) The molecular weight of Laughing Gas is 44. Find its density compared with air.

Molecular weight  $= 44$

∴ Density compared with Hydrogen  $= \frac{44}{2}$

∴ " " Air  $= \frac{44}{2 \times 14.4} = 1.4$  nearly

## Dulong and Petit's Law.

1—Very different quantities of heat are required to raise 1lb. of different substances through the same range of temperature.

If 1lb. of water at  $100^{\circ}\text{C}$  be added to 1lb. of water at  $0^{\circ}\text{C}$ , the resulting temperature is  $50^{\circ}\text{C}$ .

If 1lb. of water at  $100^{\circ}\text{C}$  be added to 1lb. of Mercury at  $0^{\circ}\text{C}$ , the resulting temperature is about  $96^{\circ}\text{C}$ .

Water is therefore said to have a greater capacity for heat than Mercury.

2—Water has a greater capacity for heat than nearly all other bodies. If we take for our unit the quantity of heat required to raise 1lb. of Water through  $1^{\circ}\text{C}$ , and call it "1," then the quantity of heat required to heat 1lb. of nearly all other substances will be less than 1, or will be a proper fraction. This fraction is called the Specific-heat of that substance. The Specific-heat of a few elements is shown below.



Name.	Spec. heat.	Name.	Spec. heat.
Sodium - -	·29	Tin - -	·0548
Magnesium -	·25	Iodine - -	·0541
Potassium -	·166	Mercury - -	·0319
Iron - -	·112	Platinum -	·0314
Zinc - -	·0955	Lead - -	·0307
Silver - -	·057	Bismuth -	·0305

3—Dulong and Petit taking *Atomic weights*, instead of *equal weights* found that the atoms of nearly all simple bodies have the same capacity for heat. The capacity for heat of the atoms (commonly called Atomic heat) is 6·4 times the capacity for heat of the unit of weight of water.

4—From this generalisation we can deduce the following relations, which will enable us to determine Atomic weights from Specific-heats:—

Atomic weight of Element : Unit weight of Element.  
 :: Atomic heat : Specific heat.  
 :: 6·4 : Specific heat.

$$\therefore \frac{\text{Atomic weight}}{1} = \frac{6·4}{\text{Sp. heat}}$$

$$\text{that is Atomic weight} = \frac{6·4}{\text{Sp. heat.}}$$

Examples (1): The Specific heat of Lead is ·0307. What is its Atomic weight?

$$\text{Atomic weight} = \frac{6·4}{·0307} = 207 \text{ nearly.}$$

(2) The Atomic weight of Iodine is 127; find its Specific heat.

$$\text{Sp. heat} = \frac{6·4}{127} = ·054.$$





5—The application of Dulong and Petit's Law has been extended to Compounds.

Molecular weight multiplied by the Specific heat of the Compound =  $n$  (6.4), where  $n$  is the number of atoms in the molecule.

6—The Atomic heats of the following Elements are anomalous as at present determined.

Hydrogen =	2.4	Boron =	5.5
Oxygen =	4.1	Carbon =	5.5
Nitrogen =	5.5.	Silicon =	5.5

7—As a corollary to Avogadro's Law we observe that equal volumes of Elementary Gases require the same amount of heat to raise their temperature through one degree.

## Mitscherlich's Law of Isomorphism.

1—*Law*—Identity of Crystalline form indicates analogy of Chemical constitution.

2—Ammonia and Hydrochloric Acid form a compound whose molecule consists of six atoms. The compound has the same crystalline form as the compound of Potassium with Chlorine, whose molecule consists of two atoms, and whose formula is KCl. Therefore we assign to the Ammonia compound a similar formula—AmCl, where Am stands for  $\text{NH}_4$ , a group analogous to K.

3—Similar considerations have led to new arrangements of old formulæ, and to consequent modifications of Atomic and Molecular weights.

4—When a body crystallizes in two or more systems it is said to be dimorphous or polymorphous. This constitutes dimorphism or polymorphism. Bodies that have no obvious crystalline form are said to be amorphous.

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## Determination of Atomic Weights.

### *First Method—Vapour density.*

1—Equal volumes of Elementary Gases contain the same number of molecules.

2—The molecular volume is twice the volume occupied by the atom of Hydrogen. Therefore the Atomic weights of Elementary Gases are as the densities of the gases.

3—Example:—The density of a certain Elementary Gas compared with air is 1.5. Find its Atomic weight.

Air is 14.4 times as heavy as Hydrogen. Therefore the density of the Elementary Gas compared with Hydrogen is  $14.4 \times 1.5 = 21.6$ . The Atomic weight of the Gas is 21.6.

### *Second Method—Least Weight.*

1—The Atomic weight of an Element is the smallest weight which enters into or is expelled from chemical combination in the molecular weight of any of its gaseous compounds.

This is a corollary from the doctrine of atoms.

The molecular weight of the gaseous compound is known from its vapour-density. The percentage composition of the compound must then be ascertained by analysis or by synthesis. Then, since the amount of the Element present in 100 parts of the gaseous compound is known, the amount present in the molecular weight can be easily calculated. The application of this principle is exemplified in the following table.



# Table showing the Atomic Weight of Nitrogen.

Names of Bodies.	Molecular Weights, H = 2.	Percentage Composition.	Proportions to determine the quantity of Nitrogen contained in the Molecule.	Quantitative composition of Molecules.	
				Nitrogen.	Other Elements.
Nitrogen	28			28	0
Nitrous Oxide	44	Oxygen = 36.33 Nitrogen = 63.67	100 : 63.67 : : 44 : x =	28	16 of Oxygen
Nitric Oxide	30	Oxygen = 53.33 Nitrogen = 46.67	100 : 46.67 : : 30 : x =	14	16 of Oxygen
Nitric Peroxide	46	Oxygen = 69.56 Nitrogen = 30.44	100 : 30.44 : : 46 : x =	14	32 of Oxygen
Nitric Anhydride	108	Oxygen = 74.08 Nitrogen = 25.92	100 : 25.92 : : 108 : x =	28	80 of Oxygen
Ammonia	17	Hydrogen = 17.64 Nitrogen = 82.36	100 : 82.36 : : 17 : x =	14	3 of Hydrogen

From this Table it is seen that the smallest quantity of Nitrogen found in a Molecule of any of its compounds is 14. This, therefore, is taken to be the Atomic weight of Nitrogen.





*Third Method—Dulong and Petit's Law.*

$$\text{Atomic weight} = \frac{6.4}{\text{Specific heat.}}$$

For example, the Specific heat of Iron is .112.

Now,  $\frac{6.4}{.112} = 56$ , which is the Atomic weight of Iron.

*Fourth Method—Equivalents.*

1—That quantity of an Element which can combine with or displace the unit weight of Hydrogen is called the equivalent of that Element.

2—The Atomic weight is the equivalent or a multiple of it. What multiple the Atomic weight is of the equivalent is determined by comparison with the results of the Third method. Dulong and Petit's law supplements the method of Equivalents, but the latter method is capable of greater accuracy. The two methods are, therefore, used in conjunction.

3—We find by experiment that one gramme of Hydrogen is displaced by 28 grammes of Iron. We have seen by Dulong and Petit's Law that the Atomic weight of Iron is 56. In this case the Atomic weight is twice the combining proportion,  $56 = 2 \times 28$ .

4—The equivalent of an Element may be determined by finding the weight of it that combines with another radicle whose equivalent is already known.

We find by experiment that 1.3305 grammes of Copper will yield 1.6675 grammes of Cupric Oxide. Therefore the amount of Oxygen with which the Copper has combined is  $1.6675 - 1.3305 = .337$  grammes. Now, if .337 grammes combine with 1.3305, then 8 grammes (the equivalent of Oxygen) will combine with 31.2 grammes of Copper, and 31.2 is the equivalent of Copper.

5—The following is a table of the Atomic weights of the principal elements :—



## Table of Equivalents and Atomic Weights.

Name of Elements.				Equivalent, <i>i.e.</i> , the weight that combines with or displaces one gramme of Hydrogen	Atomic Weight.
Aluminium	...	...	...	9	27
Antimony	...	...	...	40	120
Arsenic	...	...	...	25	75
Barium	...	...	...	68.3	137
Bismuth	...	...	...	70	210
Boron	...	...	...	3.7	11
Bromine	...	...	...	80	80
Cadmium	...	...	...	56	112
Calcium	...	...	...	20	40
Carbon	...	...	...	2.9	12
Chlorine	...	...	...	35.5	35.5
Chromium	...	...	...	26.2	52.5
Cobalt	...	...	...	29.5	59
Copper	...	...	...	31.75	63.5
Fluorine	...	...	...	19	19
Gold	...	...	...	65.5	196.6
Hydrogen	...	...	...	1	1
Iodine	...	...	...	127	127
Iron	...	...	...	28	56
Lead	...	...	...	103.5	207
Magnesium	...	...	...	12	24
Manganese	...	...	...	27.5	55
Mercury	...	...	...	100	200
Nickel	...	...	...	29.5	59
Nitrogen	...	...	...	4.7	14
Oxygen	...	...	...	8	16
Palladium	...	...	...	26.53	106
Phosphorus	...	...	...	10.3	31
Platinum	...	...	...	49.25	197
Potassium	...	...	...	39	39
Silicon	...	...	...	7	28
Silver	...	...	...	10	108
Sodium	...	...	...	23	23
Strontium	...	...	...	43.75	87.5
Sulphur	...	...	...	16	32
Tin	...	...	...	29.5	118
Zinc	...	...	...	32.5	65





## Valency.

1—Atoms, and also groups of Atoms, have the power of combining with or displacing other Atoms or groups of Atoms.

2—The Valency of an elementary Atom is a number expressing the maximum number of Hydrogen Atoms which this elementary Atom can combine with or displace.

3—The Atoms of Elements are called *simple radicles*.

A group of Atoms forming a constant constituent in a series of compounds, and replaceable by simple radicles is called a *compound radicle*.

4—We have now to deal with the Valency of (1) the *simple radicles*; and of (2) the *compound radicles*.

The following are characteristic compounds of other elements with Hydrogen:—

$\text{HCl}$ Hydrochloric Acid	$\text{H}_2\text{O}$ Water	$\text{H}_3\text{N}$ Ammonia	$\text{H}_4\text{C}$ Marsh Gas
$\text{HF}$ Hydrofluoric Acid	$\text{H}_2\text{S}$ Sulphuretted Hydrogen	$\text{H}_3\text{P}$ Phosphuretted Hydrogen	$\text{H}_4\text{Si}$ Siliciuretted Hydrogen

5—Chlorine and Fluorine, which combine with one Atom of Hydrogen, are said to be monovalent. Oxygen and Sulphur are divalent. Nitrogen and Phosphorus are trivalent. Carbon and Silicon tetravalent.

6—The term Valency must not be confounded with the term Equivalent. The Valency of an Atom is the number of Hydrogen Atoms which it can combine with or displace.

The Valency of Zinc is 2, or it is said to be a Dyad because an atom of Zinc displaces 2 atoms of Hydrogen.

The Equivalent of an Element is the weight of it that can combine with it or displace the unit of weight of Hydrogen.

The Equivalent of Zinc is said to be 31.5, because 31.5 parts by weight of Zinc can replace 1 part by weight of Hydrogen.





In finding Valency we consider *one Atom of the element* and find the number of Atoms of Hydrogen with which it combines or which it displaces.

In finding the Equivalent we consider *unit weight of Hydrogen*, and find what weight of the element combines with or displaces this unit.

7—These terms, Monatomic, Diatomic, &c., designate the number of Atoms contained in the molecule. For there are exceptions to the general law that the molecule contains two Atoms.

The molecules of Zinc, Cadmium, and Mercury contain but one Atom. They have monatomic molecules.

The molecules of Phosphorus and Arsenic contain four Atoms. They have tetraatomic molecules.

8—The following Table presents a classification of the more important Atoms, or simple radicles, according to Valency. The marks at the top right hand corner of the symbols denote the Valency:—

I. Monads. H	II. Dyads. H <sub>2</sub>	III. Triads. H <sub>3</sub>	IV. Tetrads. H <sub>4</sub>
H'	O''	N'''	Si <sup>iv</sup>
F'	S'	B'''	C <sup>iv</sup>
Cl'		P'''	
Br'	Ca''	As'''	Sn <sup>iv</sup>
I'	Sr''	Bi'''	Pt <sup>iv</sup>
	Ba''	Au'''	
Ag'	Mg''	Sb'''	
Na'	Zn''	Cr'''	
K'	Cu''	Fe'''	
	Hg''	Al'''	
	Mn''		
	Pb''		
	Co''		
	Ni''		



9—The following Table presents a classification of the principal inorganic compound radicles:—

I. Monads. H	II. Dyads. H <sub>2</sub>	III. Triads. H <sub>3</sub>	IV. Tetrad. H <sub>4</sub>
Hydrate = HO	Carbonate = CO <sub>3</sub>	Phosphate = PO <sub>4</sub>	Pyrophosphate
Nitrate = NO <sub>3</sub>	Sulphate = SO <sub>4</sub>		= P <sub>2</sub> O <sub>7</sub>
Chlorate = ClO <sub>3</sub>			
Ammonium = NH <sub>4</sub>			

11—The following selection of compounds will illustrate the application of these principles. It will be seen that members of the same group combine radicle for radicle. Dyads combine with two Monads. Two Dyads will combine with one Tetrad. Three Dyads combine with two Triads and so on.

H'Cl'	Hydrogen Chloride
H'I'	Hydrogen Iodide
Ag'Cl'	Silver Chloride
(NH <sub>4</sub> )' (NO <sub>3</sub> )'	Ammonium Nitrate
Pb''(NO <sub>3</sub> ) <sub>2</sub> '	Lead Nitrate
K' <sub>2</sub> O''	Potassium Oxide
Ag' <sub>2</sub> S''	Silver Sulphide
Ba''O''	Barium Oxide
Ba''Cl' <sub>2</sub>	Barium Chloride
Ca''(SO <sub>4</sub> )''	Calcium Sulphate
Ca'' <sub>3</sub> (PO <sub>4</sub> )''' <sub>2</sub>	Calcium Phosphate
Bi'''Cl' <sub>3</sub>	Bismuth Chloride
H' <sub>3</sub> PO <sub>4</sub>	Hydrogen Phosphate
F <sub>2</sub> O <sub>3</sub>	Ferric Oxide





## Chemical Nomenclature and Notation.

Chemistry possesses a strictly scientific nomenclature, together with a corresponding symbolic notation. Every element and every compound not only has a correct scientific name, but also a symbol or formula by which it can be represented in notation.

So closely do the nomenclature and the notation correspond, that, after an exposition of the principles of nomenclature and of notation, the name will be evident from the formula, and the formula from the name.

### I.—Nomenclature.

1—The great principle is that the constitution of the compound is signified by the name employed.

2—Compounds are said to be binary, ternary, etc., according to the number of Elements that make up the compound.

3—The nomenclature of binary compounds is based upon certain electrical characters of the elements. When Water, which is a compound of Oxygen and Hydrogen, is subjected to the action of a strong electric current, the elements separate. Oxygen appears where the current enters. Hydrogen appears where the current leaves. The Hydrogen, goes, as it were, with the current, and so is said to be *positive*. The Oxygen remains, as it were, against the current, and so is said to be *negative*. Now, although the elements cannot be sharply divided into two classes, positive and negative, yet they can be arranged so that each is positive to all that follow it.



The following is such an arrangement of the more important elements:—

Potassium	+	Positive
Sodium		
Magnesium		
Zinc		
Iron		
Aluminium		
Lead		
Tin		
Bismuth		
Copper		
Mercury		
Platinum		
Gold		
Hydrogen		
Antimony		
Carbon		
Phosphorus		
Sulphur		
Oxygen		
Bromine		
Iodine		
Chlorine	—	Negative

From this Table it will be observed that the Metals are as a class positive to the remainder.

4—In nomenclature the name of the more positive element comes first. Thus we speak of Potassium Chloride, and we write KCl and not ClK.

5—When a pair of elements form only one compound, the name denoting the negative element ends in *ide*, e.g., *Potassium Chloride*, *Hydrogen Chloride*, *Magnesium Chloride*.



6—When the same elements unite in two proportions the positive element ends in *ous* for the lower proportion of the negative element, and in *ic* for the higher proportion. Thus from the name *Stannous Chloride* we learn that this compound contains less Chlorine than *Stannic Chloride*.

Similarly *Nitrous Oxide* contains less Oxygen than *Nitric Oxide*.

7—If the elements unite in more than two proportions, a proportion of the negative element lower than the proportion found in the *ous* compound is indicated by prefix *Hypo*. Thus *Hypochlorous Oxide* contains less Oxygen than *Chlorous Oxide*. A proportion of the negative element greater than the proportion present in the *ic* compound is indicated by the prefix *Per*. Thus *Perchloric Oxide* indicates a higher proportion of Oxygen than is found in *Chloric Oxide*.

8—When compounds of the same elements are very numerous, recourse is commonly had to Greek numerals. The prefixes mono, di, tri, tetra, penta, indicate the number of Atoms of the negative element present. The term "*Sesqui*," meaning one-and-a-half is used when the ratio is as 2 to 3. The name *Ferric Sesquioxide* indicate an Oxide where the Atoms of Iron and Oxygen are in the ratio of 2 to 3.

9—Before proceeding further into the subject of Nomenclature, we shall expound the principles of Notation. We can then resume the exposition of Nomenclature and Notation side by side.

## II—Notation.

1—To every element there is a symbol which is usually one or two letters of its Latin name.

Thus, C = Carbon	Cu = Copper
Ca = Calcium	Co = Cobalt
Cd = Cadmium	Cr = Chromium
Mg = Magnesium	Mn = Manganese
Hg = Mercury.	





2—This symbol does not denote simply the element. It denotes the *Atomic weight* of the element. Thus Ag should be used not as an abbreviation for *Silver*, but for 108 parts by weight of *Silver*. Similarly  $2\text{Ag}$ , or  $\text{Ag}_2$  denotes  $2 \times 108$  parts of *Silver*. Symbols should be employed in a *quantitative sense only*.

3—*Compounds* are symbolised by writing the symbols of the constituents after each other. The number of Atoms of each constituent present is denoted by a small numeral at the bottom right hand corner of the symbol. Thus  $\text{Ag}_2\text{O}$  signifies Silver Oxide, consisting of 2 atoms of Silver united to an Atom of Oxygen, or, by weight.  $2 \times 108 + 16 = 232$  parts of Silver Oxide.  $2\text{Ag}_2\text{O}$  signifies 2 molecules of Silver Oxide, or  $2 \times 232$  parts by weight of Silver Oxide. A numeral prefixed to a compound or any part of a compound multiplies all that follows it. The same thing is also signified by enclosing the elements in a bracket, and placing the numeral at the bottom right hand corner. Thus,  $\text{Pb}_2\text{NO}_3$  and  $\text{Pb}(\text{NO}_3)_2$  signify the same thing.

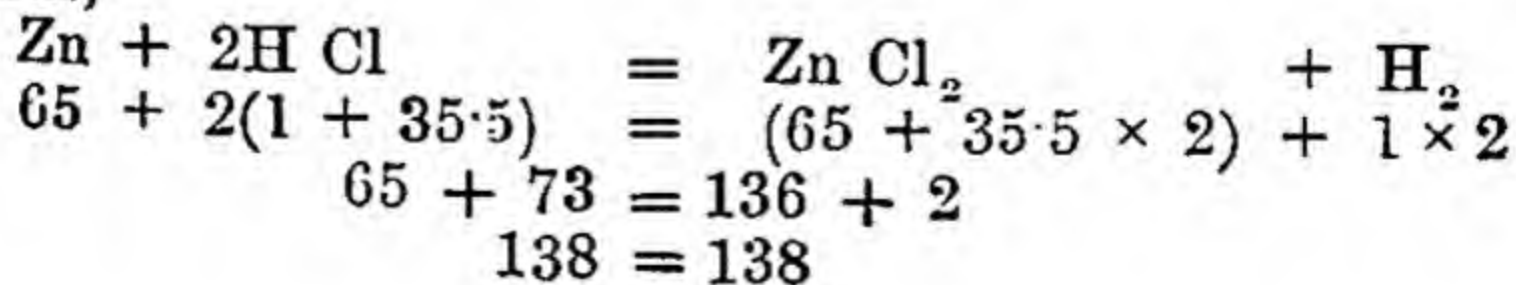
4—The sign  $+$  placed between two symbols signifies that the bodies are in conjunction or mixed.

$\text{K}_2 + \text{O}_2$  signifies  $2 \times 39.1$  parts, by weight, of Potassium in contact with  $2 \times 16$  parts, by weight, of Oxygen.

5—The sign  $=$  is used in the sense of “yields” or “produces.”

6—Chemical changes are represented by formulæ arranged in equations. The two sides of the equation represent equal weights of matter.

Thus,

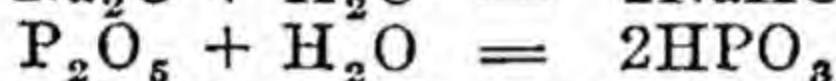
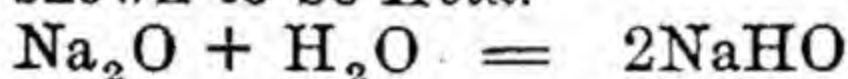




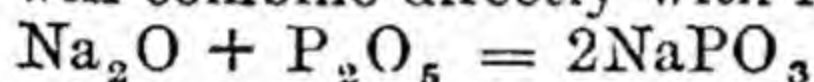
### III.—Nomenclature and Notation.

1—If a piece of Sodium and a piece of Phosphorus be separately burnt in air, we obtain an Oxide of each. These Oxides can be denoted by the formulæ  $\text{Na}_2\text{O}$  and  $\text{P}_2\text{O}_5$  respectively. They are named Sodium Monoxide and Phosphorus Pentoxide respectively.

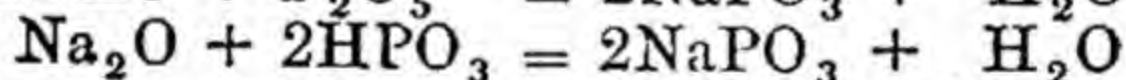
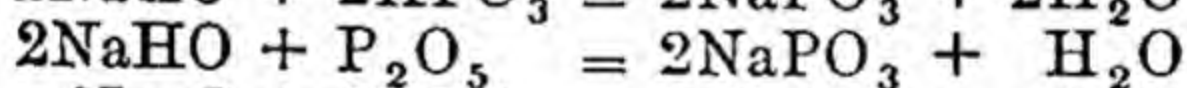
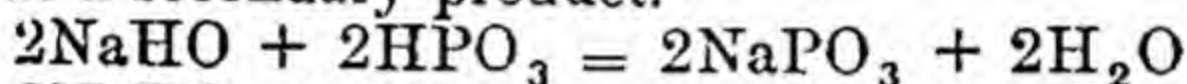
2—These Oxides manifest their opposite properties by their action on Water. The solution of Sodium Oxide turns red litmus blue, and is thereby shown to be *Alkaline*. The solution of Phosphorus Pentoxide reddens blue litmus, and is thereby shown to be *Acid*.



3—Sodium Oxide is electro-positive to Phosphorus Pentoxide, and will combine directly with it.

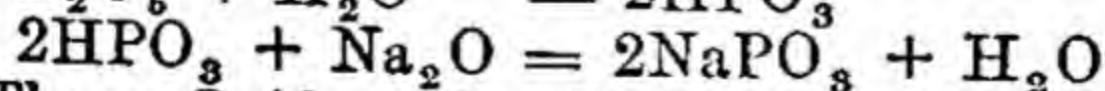
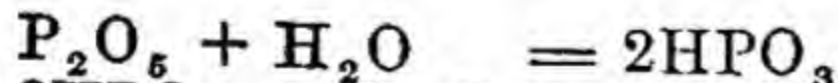


4—If instead of one or both of the Oxides we substitute the Hydrated Oxide ( $\text{NaHO}$  or  $\text{HPO}_3$ ), we obtain the same product  $\text{NaPO}_3$ , and the Water reappears in the equation as a secondary product.



5—The more positive elements, such as the metals, form Oxides like Sodium Oxide, though they do not always yield *Alkaline* solutions. The more negative elements, the non-metals, form Oxides like Phosphorus Pentoxide.

6—The Oxides like Phosphorus Pentoxide, which combine with Water, yielding Acids, are called *Anhydrides*.

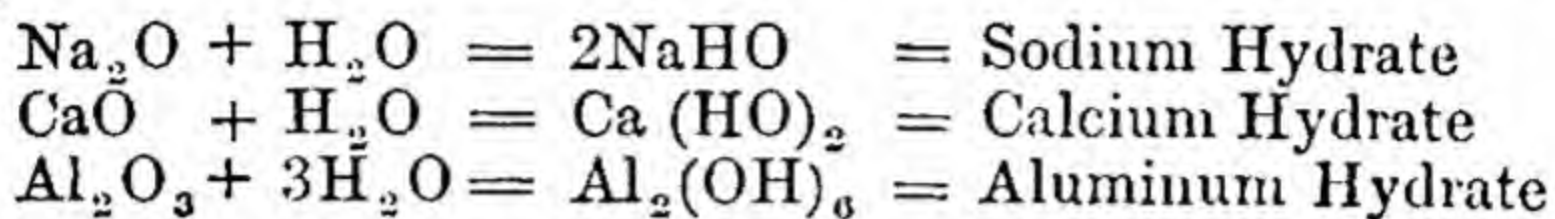


7—Those Oxides like Sodium Oxide, which, either before or after being acted on by Water, will react with *Anhydrides* or *Acids*, are called *Basic Oxides*. The pro-

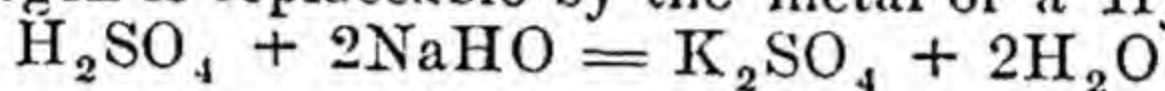




duct of the combination of a Basic Oxide with Water is called a **Hydrate**. All Hydrates contain the grouping HO.



8—An **Acid** may be defined as a compound which contains Hydrogen replaceable by the metal of a Hydrate, the displaced H combining with the (HO) grouping of the Hydrate to form  $\text{H}_2\text{O}$ .  $\text{H}_2\text{SO}_4$  is an Acid. It can be formed by the union of the Anhydride,  $\text{SO}_3$ , with Water. Its Hydrogen is replaceable by the metal of a Hydrate.

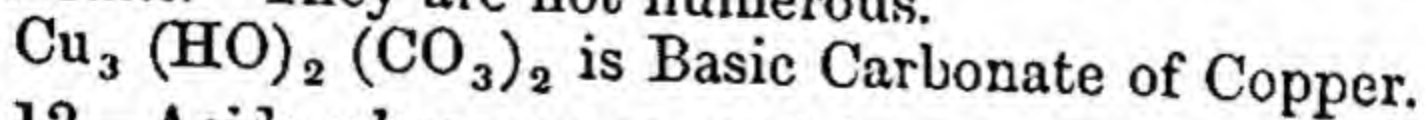


9—Acids which contain one Atom of replaceable Hydrogen are called *monobasic*. If they contain two such Atoms they are called *dibasic*, &c. For example, HCl,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_3\text{PO}_4$ , are monobasic, dibasic, and tribasic, respectively.

10—When Basic Oxides or Hydrates act on Acids, the compound formed by the replacement of the Hydrogen of the Acid by the metal of the base is called a **Salt**. Thus  $\text{K}_2\text{SO}_4$  is a *salt* called Potassium Sulphate. An Acid may be regarded as a salt whose base is Hydrogen.

Salts are said to be Acid or Normal according as the whole or a part only of the Hydrogen is displaced. Thus  $\text{KHSO}_4$  is an *Acid Salt*.  $\text{K}_2\text{SO}_4$  is the *Normal Salt*.

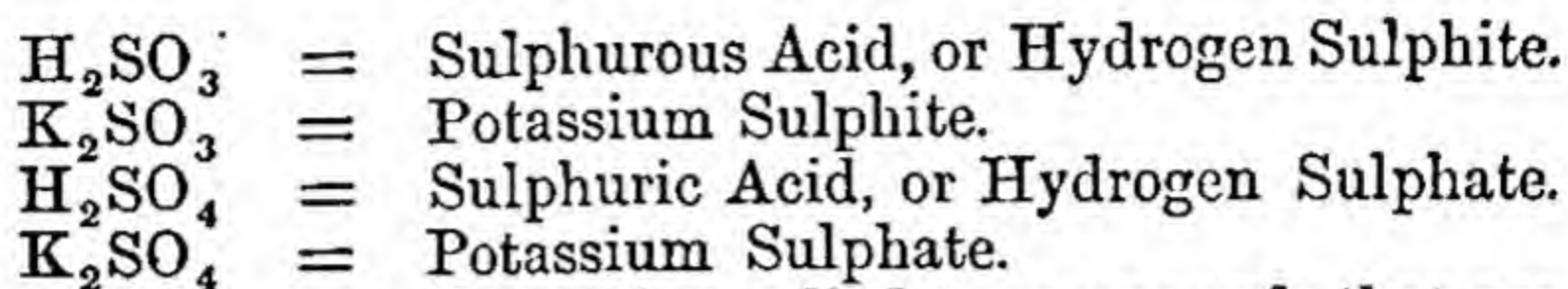
11—Sometimes a metal is united partly with the group HO and partly with an Acid radicle. Such salts are called *Basic Salts*. They are not numerous.



12—Acids whose names end in *ous* form salts whose names end in *ite*. Acids whose names end in *ic* form salts whose names end in *ate*.







13—The term **Base** is applied to compounds that are converted into salts with acids either by the formation of no secondary product, or of Water only.

These compounds are *Metallic Oxides, Hydrates*, and the *Hydrides* of Nitrogen, Phosphorus, Arsenic, and Antimony.

## Chemical Arithmetic.

### Metric System of Weights and Measures.

1 metre = 39.37 inches	1 gramme = 15.43 grains
10 metres = 1 decametre	10 grammes = 1 decagramme
100 metres = 1 hectometre	100 grammes = 1 hectogramme
1000 metres = 1 kilometre	1000 grammes = 1 kilogramme
$\frac{1}{10}$ metre = 1 decimetre	$\frac{1}{10}$ gramme = 1 decigramme
$\frac{1}{100}$ metre = 1 centimetre	$\frac{1}{100}$ gramme = 1 centigramme
$\frac{1}{1000}$ metre = 1 millimetre	$\frac{1}{1000}$ gramme = 1 milligramme
1 litre = a cubic decimetre, or,	
1000 cubic centimetres = 61.92 cubic inches	
1 litre of water at 4°C weighs 1000	
grammes (put in value in pts. or qts.)	
1 gallon = 4.534 litres	

### I.—On the Relation between Weight and Volume.

1—One gramme of Hydrogen at a temperature of 0°C and under a pressure of 760 millimetres of Mercury occupies 11.2 litres.



Since the densities of the simple gases are in same ratio as their combining weights, it may be stated generally that the combining weight in grammes of a simple gas occupies 11.2 litres when the temperature is  $0^{\circ}\text{C}$  and the pressure 760mm.

Thus, 16 grammes of Oxygen, 14 grammes of Nitrogen, 35.5 grammes of Chlorine, occupy severally 11.2 litres at  $0^{\circ}\text{C}$  and 760mm pressure.

3—If it be required to find, say, the weight of 40 litres of Oxygen, at  $0^{\circ}\text{C}$  and 760mm., the process is as follows:—

11.2 litres at $0^{\circ}\text{C}$ and 760 mm.	weigh 16 grammes
∴ 1 litre	weighs $(16 \div 11.2)$ grammes
and 40 litres	weigh $(16 \div 11.2) \times 40 \text{ grms} = 57.1 \text{ grms.}$

4—If it be required to find the volume of 20 grammes of Nitrogen at  $0^{\circ}\text{C}$  and 760 mm., the process is as follows:—

14 grms of Nitrogen at $0^{\circ}\text{C}$ & 760mm.	occupy 11.2 litres
∴ 1 gramme	occupies $(11.2 \div 14)$ litres
and 20 grammes	occupy $(11.2 \div 14) \times 20$ litres

5—Since the densities of the compound gases are as their *molecular* weights, it may be stated generally that the molecular weight in grammes of a compound gas occupies 22.4 litres at  $0^{\circ}\text{C}$  and 760mm. The molecular volume—that is to say, the volume occupied by the molecular weight (expressed in grammes) is 22.4 litres.

6—In the following simple substances the relation between weight and volume is anomalous:—

Mercury	Hg	200 grammes	occupy 22.4 litres
Cadmium	Cd	112	22.4 "
Zinc	Zn	56	2.24 "
Phosphorus	P	31	5.6 "
Arsenic	As	75	5.6 "





7—In the following compound gases the relation is anomalous, and is set forth below:—

Name.	Formula.	Weight in grammes.	Volume in litres.
Nitric Oxide ... ..	$\text{N}_2 \text{O}_2$	60	44.8
Pernitric Oxide ... ..	$\text{N}_2 \text{O}_4$	86	44.8
Chlorous Oxide ... ..	$\text{Cl}_2 \text{O}_3$	119	44.8
Perchloric Oxide .. ...	$\text{Cl}_2 \text{O}_4$	135	44.8
Mercurous Chloride ... ..	$\text{Hg}_2 \text{Cl}_2$	271	44.8
Ammonium Chloride ... ..	$(\text{NH}_4) \text{Cl}$	535	44.8
Arsenous Oxide ... ..	$\text{As}_2 \text{O}_3$	198	11.2

8—In the foregoing examples we have considered *the volume of the unit of weight*. It is often more convenient to consider *the weight of the unit of volume*. As the gramme is taken as the unit of weight, so one litre is taken on the unit of volume.

9—The weight of one litre of Hydrogen at  $0^\circ\text{C}$  and 760 mm. is .0896 grammes.

10—To find the weight of a litre of any gas, simple or compound, all that is necessary is to multiply .0896 by the density of that gas compared with Hydrogen.

11—Thus the weight of a litre of Nitrogen is  $14 \times .0896$  grammes; and the weight of a litre of Hydrochloric Acid gas ( $\text{HCl} = 2$  vols.) is  $\frac{1 + 35.5}{2} \times .0896$  grammes  $\approx 1.63$  grammes.





## II.—On the Variation of the Volume of a Gas for Temperature and Pressure.

### A.—Volume and Temperature.

1—Gases expand  $\frac{1}{273}$  part of their volume at  $0^{\circ}\text{C}$  for every increase of temperature  $1^{\circ}\text{C}$ .

Thus 273 vols. of gas at	$0^{\circ}\text{C}$	become
274 „ „	$1^{\circ}\text{C}$	„
275 „ „	$2^{\circ}\text{C}$	„
$273 + n$ „ „	$n^{\circ}\text{C}$	„
Similarly, 273 vols. „	$0^{\circ}\text{C}$	„
272 vols. „	$-1^{\circ}\text{C}$	„
271 vols. „	$-2^{\circ}\text{C}$	„
$273 - 273 = 0$ at	$-273^{\circ}\text{C}$	

This temperature— $273^{\circ}$  is called absolute Zero. Temperature can always be expressed on the absolute scale by adding 273 to the given temperature.

2—Hence we have the general law that the volume of a gas varies with its absolute temperature.

3—Alterations in volume can be calculated by the following proportion:—

As  $273 + \text{given temperature} : 273 + \text{required temperature} :: \text{given volume} : \text{required volume}$ .

4—The decimal fraction corresponding to  $\frac{1}{273}$  is  $\cdot 00366$ .  
Thus, 1 vol. of gas at  $0^{\circ}\text{C}$  becomes  $1 + \cdot 00366 \times 1$  at  $1^{\circ}\text{C}$ .  

1	„	„	$1 + \cdot 00366 \times 2$ at $2^{\circ}\text{C}$ .
1	„	„	$1 + \cdot 00366 \times n$ at $n^{\circ}\text{C}$ .

5—Hence if  $V^{\circ}$  be any weight of gas at  $0^{\circ}$  and  $V^n$  its volume at  $n^{\circ}\text{C}$ .

$$\frac{V^{\circ}}{V^n} = \frac{273}{273 + n} = \frac{1}{1 + \cdot 00366 \times n}$$

or  $V^n = V^{\circ} (1 + \cdot 00366 \times n)$ .



6—A certain quantity of gas occupies 7 litres at  $0^{\circ}\text{C}$ . Find the volume occupied at  $100^{\circ}\text{C}$ .

$$273 + 0 : 273 + 100 :: 7 : x \quad 9.56 \text{ litres ; or vol. at } 100^{\circ}\text{C} = 7 (1 + .00356 \times 100) = 9.56 \text{ litres.}$$

## B.—Volume and Pressure.

1—The volume of gas varies inversely with the pressure upon it. If the pressure on a gas becomes 2, 3, or 4 times the original amount, the volume becomes  $\frac{1}{2}$ ,  $\frac{1}{3}$ , or  $\frac{1}{4}$  of the original volume.

If  $V =$  vol. of a gas under a pressure  $P$   
 $V' =$  " another pressure  $P'$   
 Then  $V : V' :: P' : P$ .

2—If a certain weight of gas occupies 20 litres at a pressure of 730mm, what will occupy at 760mm. ?

$$760 : 730 :: 20 : x = 19.21.$$

## C.—Volume with Temperature and Pressure.

1—Since, when pressure is constant and temperature varies,

$$\frac{V^0}{V_n} = \frac{273 + 0}{273 + n} = \frac{1}{1 + .00366n}$$

and when temperature is constant and pressure varies,

$$\frac{V_n}{V'} = \frac{P'}{P}$$

therefore, when both temperature and pressure vary,

$$\frac{V^0}{V'} = \frac{273}{273 + n} \times \frac{P'}{P}$$

where  $n^0$  is the new temperature at  $P'$ , the new pressure.



2—If 12 litres of a gas are at a pressure of 765 mm., and a temperature of  $5^{\circ}\text{C}$ , find the pressure of the same gas when occupying 18 litres at a temperature of  $35^{\circ}\text{C}$ .

$$\frac{12}{18} = \frac{273 + 5}{273 + 35} \times \frac{P'}{765} \therefore P' = 565.3.$$

### III—To calculate the Percentage Composition of a Compound.

1—Suppose it is required to find the percentage composition of Water,  $\text{H}_2\text{O}$ .

$$\left. \begin{array}{l} \text{H}_2 = 2 + 1 = 2 \\ \text{O} = 16 = 16 \end{array} \right\} = 18$$

whence we see that 18 of Water contains 2 of Hydrogen and 16 of Oxygen. Therefore to find the amount of each in 100 parts of Water, the following proportion is taken:—

$$\begin{array}{lcl} \text{H}_2\text{O} : \text{H}_2 :: \text{Water} : \text{Hydrogen} \\ 18 : 2 :: 100 : 11.11 \\ \text{H}_2\text{O} : \text{O} :: \text{Water} : \text{Oxygen} \\ 18 : 16 :: 100 : 88.9 \end{array}$$

### IV—To determine a Formula for a substance from its Percentage Composition.

1—Suppose it is required to find a formula for a substance shown by analysis to have the following composition:—

$$\left. \begin{array}{l} \text{Carbon} = 27.27 \\ \text{Oxygen} = 72.73 \end{array} \right\} = 100.$$

The Problem here is to find the relative number of Carbon and of Oxygen Atoms present. Therefore, the first step is to divide the percentage quantity of each element by





its Atomic weight. The next step is to reduce these results to simple ratios expressed by integers.

$$\text{Atoms of Carbon } 27.27 \div 12 = 2.2727$$

$$\text{Oxygen } 72.73 \div 16 = 4.5454$$

and

$$2.2727 \div 2.2727 = 1 = \text{Carbon}$$

$$4.5454 \div 2.2727 = 2 = \text{Oxygen}$$

The formula is therefore  $\text{CO}_2$ .

3—Find a formula for a substance which on analysis yielded the following results:—

$$\left. \begin{array}{l} \text{H} = 2.04 \\ \text{O} = 65.31 \\ \text{S} = 32.65 \end{array} \right\} = 100.$$

$$\text{Atoms of Hydrogen } 2.04 \div 1 = 2.04$$

$$\text{Oxygen } 65.31 \div 16 = 4.08$$

$$\text{Sulphur } 32.65 \div 32 = 1.02$$

$$\text{Now } 2.04 \div 1.02 = 2 = \text{Hydrogen}$$

$$4.08 \div 1.02 = 4 = \text{Oxygen}$$

$$1.02 \div 1.02 = 1 = \text{Sulphur.}$$

The formula is  $\text{H}_2\text{SO}_4$ .

## V—To calculate the Amount of a Compound that can be formed from a given weight of one of its Constituents.

1—Suppose it is required to know how much Water can be prepared by the combustion of 12 grammes of Hydrogen.

Now, we know by quantifying the formula for Water that 2 parts of Hydrogen will yield 18 parts of Water. The amount given by 12 can be ascertained by the following proportion:—

$$\begin{array}{l} \text{H}_2 : \text{H}_2\text{O} :: \text{Hydrogen} : \text{Water} \\ 2 : 18 :: 12 : x = 108. \end{array}$$



## VI—To calculate the Weight of any Radicle that can be formed by the decomposition of a Compound.

1—How much Oxygen can be obtained from 50 grammes of  $\text{KClO}_3$  Potassium Chlorate?

The molecular weight of  $\text{KClO}_3$  is 122.6, and this weight contains 48 parts of Oxygen. The amount that can be obtained from 50 grammes will be given the following proportion:—

$$\begin{array}{l} \text{KClO}_3 : \text{O}_3 :: \text{Pot Chlorate} : \text{Oxygen} \\ 122.6 : 48 :: 50 : x = 19.5 \text{ grammes.} \end{array}$$

2—This weight can, if required, be converted into volume. But it will be seen that the *volume* may be calculated directly.

Thus 122.6 grammes yield  $3 \times 11.2$  litres

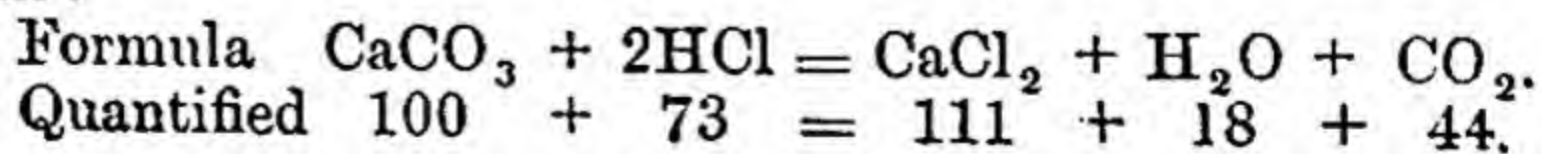
1 gramme yields  $(3 \times 11.2 \div 122.6)$  litres

and 50 grammes yield  $(3 \times 11.2 \div 122.6) \times 50$  litres.

## VII—To calculate the Weight or Volume of a substance produced in double decompositions.

1—Always write down the equation and quantify it for weight or for volume as the case may be. The ratios of the substances involved in this equation will afford material to form a proportion with the corresponding quantities in the question.

2—What weight of Calcium Chloride can be prepared by the action of 20 grammes of Hydrochloric Acid on Chalk?







Whence we see that 73 grammes of HCl yields 111 grammes of Calcium Chloride. We have, therefore, the following proportion:—

$$2\text{HCl} : \text{CaCl}_2 :: \text{Hydrochloric Acid} : \text{Calcium Chloride}$$

$$73 : 111 :: 20 : x = 13.7 \text{ grms.}$$

3—What volume of  $\text{CO}_2$  can be obtained from one kilogramme of Chalk?

$$\text{Formula} \quad \text{CaCO}_3 + 2\text{HCl} = \text{CaCl}_2 + \text{CO}_2$$

$$\text{Quantified} \quad 100 + 73 = 111 + 22.4 \text{ litres.}$$

Whence we see that 100 grammes yields 22.4 litres.

We have, therefore, the following proportion:—

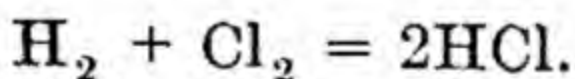
$$\text{CaCO}_3 : \text{CO}_2 :: \text{Chalk} : \text{Carbonic Acid}$$

$$100 : 22.4 :: 1000 : x = 224 \text{ litres.}$$

## VIII—Equations for Gaseous Reactions.

1—The combination and decomposition of gases by volume is capable of very simple treatment. According to Gay-Lussac's Law, gases combine in volumes that have some very simple relation to each other. These simple relations can be deduced from the quantified equation for the reaction.

2—For example, Hydrogen and Chlorine yield Hydrochloric Acid



$$\text{By weight} \quad 2 + 71 = 73 \text{ grammes}$$

$$\text{By volume} \quad 22.4 + 22.4 = 44.8 \text{ litres}$$

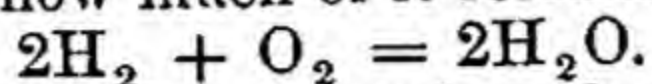
or in lowest terms and generally 1 vol. + 1 vol. = 2 vols.

3—Whatever be the number of Atoms forming a compound gas, the molecular weight in grammes of that gas occupies 22.4 litres under the normal conditions of  $0^\circ\text{C}$  and 760mm pressure.



4—The following example will exemplify this method:—

300cc of Oxygen are mixed with 500cc of Hydrogen.  
What volume of steam at  $0^{\circ}\text{C}$  and 760mm is produced?  
Which gas, and how much of it remains in excess?



$$2 \text{ vols.} + 1 \text{ vol.} = 2 \text{ vols.}$$

$$500 + 250 = 500.$$

Therefore 500cc of steam is produced, and, as only 250cc of Oxygen has been used,  $300\text{cc} - 250\text{cc} = 50\text{cc}$  will remain in excess.

---



## Classification of Elements.

1—The Elements have already been classified according to Valency. They can also be classified for analytical purposes. Elements can be arranged in groups having some common feature that will facilitate their detection in unknown substances. For example, there is a group of three (Ag, Hg, Pb), distinguished by insoluble Chlorides. There are groups characterised by insoluble Sulphides—by insoluble Carbonates—and, finally, by a marked absence of insoluble compounds. Such a classification belongs to Analytical Chemistry. It is analogous to the Analytical Classifications in Botany.

2—We have already classified Elements according to Valency. Such a classification may be compared to the Linnean System in Botany. It is based on a consideration of *one* feature, viz., the number of Atoms of Hydrogen which the Element can combine with or displace.

3—For the purposes of investigation and exposition, it is best to classify the Elements according to the totality of their common features. This may be termed the Natural Classification. Such a classification is not absolute. We cannot pass from group to group across a great break. *Natura non agit per saltum*. Classes merge into each other so gradually that between the last Element of one class, and the first Element of the adjacent class, no border-line can be sharply drawn. Yet Classes which at either extreme merge into other Classes, may, as a whole, possess well-marked common features, on account of which the Elements may be worthy of being grouped together.

### I—Metals.

1—*Certain Elements combine with Oxygen, but exhibit little or no tendency to combine chemically with each other. These are called Metals.* Since their Oxygen compounds act as bases in the formation of the Salts, they are called Basigenic.





2—The most important Metals are included in the following list:—Potassium, Sodium, Barium, Calcium, Strontium, Magnesium, Aluminium, Zinc, Cadmium, Iron, Cobalt, Nickel, Manganese, Chromium, Tin, Bismuth, Copper, Lead, Mercury, Silver, Gold, Platinum.

3—The Metals have likewise very marked physical characteristics in common.

(1) They are all solid except Mercury.

(2) They are opaque and lustrous, with great reflective power.

(3) As a class they are heavy; yet the lightest solid known (Lithium) is a metal.

(4) They are the best conductors of heat and of electricity.

(5) They are generally malleable and ductile.

4—Mixtures of Metals are called Alloys. A mixture of Mercury with any other metal is called an Amalgam.

## II—Metalloids.

1—*Certain Elements have the appearance of Metals; but while they have Basic Oxides, they have also Oxides that are Anhydrides—forming Acids. They are partly Basigenic, and partly Oxygenic or Acid producing. These are called Metalloids.*

2—The most important are the following:—Hydrogen, Arsenic, Antimony. Besides these, Chromium, Manganese, Tin, and Iron yield acid radicles, but their chemical and physical properties are generally more in accordance with the properties of the metals.

3—These Metalloids have also marked physical properties.

(1) They have the opacity, weightiness, and lustre of the Metals.

(2) They are comparatively poor conductors of heat and of electricity.



- (3) They are brittle.
- (4) Hydrogen is a gas.

4—The remarkable and distinctive peculiarities of Hydrogen will be explained when the Chemistry of that element comes up for discussion. Its position is almost unique.

### III—Non-Metals.

1—*Certain Elements, without metallic appearance, unite with Hydrogen, or one or more of their Oxides unite with Water to form Acids. These, together with Oxygen are the non-metals.* Since their leading feature is the formation of Acids, they may be termed *Oxygenic*. While the metals form Basic radicles, and are called Basigenic, these form Acid radicles, and are called Oxygenic.

2—The Elements that combine directly with Hydrogen to form Acids are Chlorine, Bromine, Iodine, Fluorine, and Sulphur.

3—The Elements which do not form Acids without Oxygen are Nitrogen, Phosphorus, Boron, Silicon, Carbon.

4—The leading physical feature in this group is that its members are electro-negative to the members of the foregoing groups.





# The Elements Grouped and Classified.

## Class I—Metals.

(A) *Metals that combine directly with Oxygen, and whose Oxides cannot be reduced by heat.*

Group I—Metals that decompose Water at ordinary temperature.

(a) Monads.	{	1 Potassium	}	Metals of the Alkalis.
		2 Sodium		
		3 Ammonium		
(b) Dyads.	{	4 Barium	}	Metals of the Alkaline Earths.
		5 Calcium		
		6 Strontium		

Group II—Metals that decompose Water at high temperature or in the presence of Acids at ordinary temperature.

Dyads.	{	7 Magnesium	}	Volatile in furnaces.
		8 Cadmium		
		9 Zinc		
(a) Valency.	{	10 Manganese	}	Not volatile in furnaces.
(b) Variable.		11 Iron		
		12 Cobalt		
		13 Nickel		
		14 Chromium.		

Group III—Metal that at red heat decomposes Water, but which cannot when 'cold decompose Water in the presence of an Acid.

15 Tin.

Group IV—Metals that decompose Water only when they are at white heat.

16 Copper.

17 Lead.

18 Bismuth.



(B)—*Metal that does not combine directly with Oxygen, and whose Oxide cannot be reduced by heat.*

19 Aluminium.

(C)—*Metals whose Oxides are readily reducible.*

Group I—Metals that combine directly with Oxygen.

20 Mercury.

21 Palladium.

Group II—Metals that cannot combine with Oxygen directly.

22 Silver.

23 Gold.

24 Platinum.

## Class II—Metalloids.

25 Hydrogen.

26 Arsenic.

27 Antimony.

## Class III—Non-Metals.

Group I—The Halogens.

28 Chlorine.

29 Bromine.

30 Iodine.

31 Fluorine.

Group II—The Sulphur Group.

32 Oxygen.

33 Sulphur.

Group III—The Nitrogen Group.

34 Nitrogen.

35 Phosphorus.

Group IV—The Carbon Group.

36 Boron.

37 Carbon.

38 Silicon.



As the Atom of this Hydrogen is taken as the unit of Atomic weight, the unit of Equivalence, and the unit of Valency, an acquaintance with Hydrogen is of primary importance. For the purposes of exposition Hydrogen will therefore come first. The non-metals will then be taken in the order of their classification.

## Hydrogen $H = 1$ .

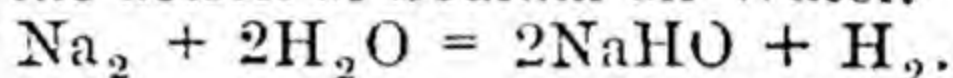
### 1—*Sources*.

Water.	Acids.	Hydrates.	Hydrides.
$H_2O$ .	$H_2SO_4$ .	$KHO$ .	$NH_3$ .

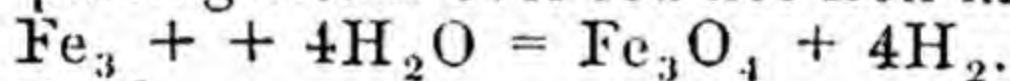
### 2—*Preparation*. (A). From Water.

(1) By electrolysing acidified Water, Hydrogen can be collected where the current leaves the Water.

(2) By the action of Sodium on Water.

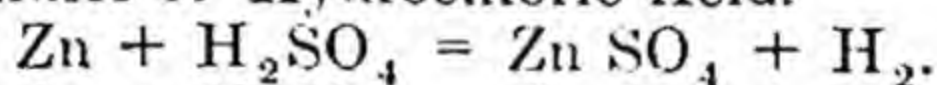


(3) By passing steam over red hot iron filings.



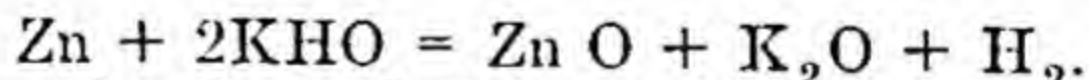
### (B.) From Acids.

(1) By the action of Zinc, Magnesium, or Iron on dilute Sulphuric or Hydrochloric Acid.

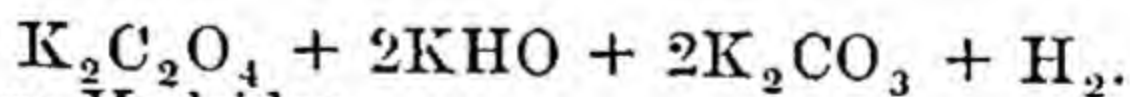


### (C.) From Hydrates.

(1) By boiling Zinc or Aluminium in Potassic Hydrate.

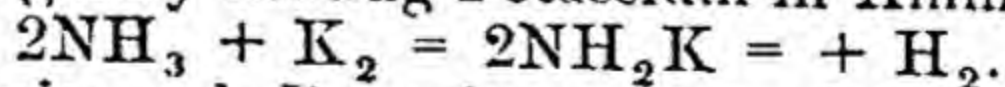


(2) By heating Potassic Oxalate with Potassic Hydrate.



### (D.) From Hydrides.

(1) By gently heating Potassium in Ammonia gas.



Ammonia and Potassium give Potassamide and Hydrogen.





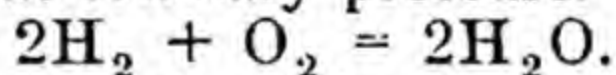
3—*Purification*—By passing the gas through a series of U tubes containing (1) Nitrate of Lead, which absorbs Sulphuretted Hydrogen, (2) Silver Sulphate which absorbs the Hydrides of Arsenic and Phosphorus, (3) Potassic Hydrate which absorbs Carbonic Acid Gas, (4) Pumice moistened with Sulphuric Acid. This last tube dries the gas.

4—*Physical Properties*—A colourless, tasteless, odourless gas. Density compared with air, .0693. Weight of one litre is .0896 gramme. It is the lightest body known. It is a good conductor of heat and of electricity—the conductivity increasing as the density is caused to increase.

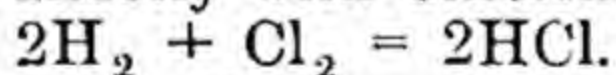
Hydrogen readily permeates through porous membranes. Gases diffuse through porous membranes at rates which are inversely proportional to the square roots of their densities. Hydrogen being the lightest body known diffuses most rapidly.

#### 5—*Reactions.*

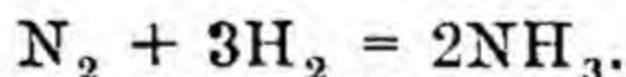
(1) Burns in Oxygen forming Water. Flame—blue, and non-luminous at ordinary pressure.



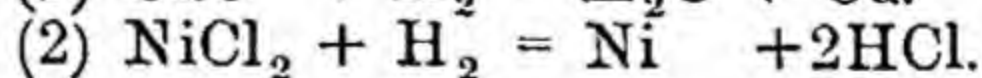
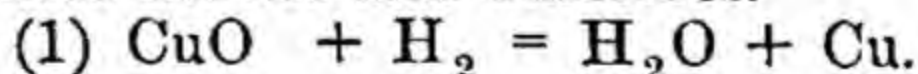
(2) Combines directly with Chlorine.



(3) Combines with Nitrogen when both are in the nascent state.



(4) Reduces Oxides and Chlorides.



#### 6—*Tests.*

(1) Lightness—the gas can be decanted upwards.

(2) Burns, but does not support combustion.

(3) Colour of flame—blue.

(4) Product of combustion—water.

#### 7—*Combustion.*



(1) We have seen (page 5) that a thermal change, definite in amount, accompanies every chemical action. When heat is absorbed, the action is said to be *endothermic*. When heat is evolved the reaction is said to be *exothermic*. Reactions are endothermic when the products are less stable than their constituents, and exothermic when the products are more stable.

(2) When exothermic reactions manifest much heat and light, one body appearing to burn away in the presence of the other, we have what is called *combustion*. The burning body is said to be "combustible." The body in which it is burning—that is to say, with which it is entering into chemical combustion—is said to be a "supporter of combustion."

(3) Bodies cannot be divided into "combustibles" and "supporters of combustion," for these terms express no absolute difference of function. Combustion is the phenomena of heat and light that accompany the union of the two bodies, irrespective of which body is the "combustible" and which is the "supporter of combustion." Oxygen will burn in Hydrogen just as Hydrogen will burn in Oxygen. The thermal phenomena are identical in both cases.

(3) The examples of combustion that are most familiar consist of bodies combining with Oxygen in Air. But the term "combustion" must no longer be confined to this class of combinations, which were the first to suggest the term. Other bodies will exhibit similar thermal phenomena. The term "combustion" is applicable to any reaction where such phenomena are present.

(4) The quantity of heat evolved is always the same whether the combustion takes place slowly or quickly.

(5) The amount of heat evolved is measured by the number of parts by weight of Water that would be raised from  $0^{\circ}\text{C}$  to  $1^{\circ}\text{C}$  by the union of the formula weights of





the reacting bodies. When two parts by weight of Hydrogen unite with 16 parts by weight of Oxygen to form 18 parts by weight of Water, the amount of heat evolved is sufficient to raise 68.924 parts by weight of Water from  $0^{\circ}\text{C}$  to  $1^{\circ}\text{C}$ .

## Hydrogenium.

1—*Allotropism*. *Elements* may change their physical properties and their chemical activity, and still remain the same Elements. Carbon exists as charcoal, graphite, and diamond. These three differ in physical properties and in chemical activity, but they agree in being the same stuff—Carbon. For when the same equal weights of each variety is burnt in Oxygen gas, the product of combustion and the weight of it are the same in each case. This change is called *allotropism*. The new varieties produced by the change are called *allotropes*, or *allotropic modifications*.

2—Allotropism is due to a rearrangement of the atoms of the mass.

3—*Isomerism*. The analogous change in *compounds* is called isomerism. Compounds that consist of the same atoms united in the same proportion may have chemical and physical properties widely different. Such compounds are said to be *isomeric*. Chalk is isomeric with Iceland Spar.

4—Hydrogen has long been regarded and treated as a Non-metal. In our classification it is placed in the middle class, the Metalloids, because it has certain well-marked resemblances to both classes.

5—It agrees with metals in the following points :—

(1) It manifests little or no tendency to combine with metals. Very few Hydrides are known.

(2) Its Oxides are Basic. Water forms Acids by union with Anhydrides



(3) Acids may be regarded as salts whose base is Hydrogen.

Compare  $\text{H}_2\text{SO}_4$  with  $\text{K}_2\text{SO}_4$ .

(4) Acids frequently crystallize, taking up water of crystallization, and then present all the appearance of ordinary salts.

(5) Palladium occludes vast quantities of Hydrogen, yielding a body that has the appearance of an alloy.

(6) It is a conductor of heat and of electricity.

(7) Hydrogen has been solidified. In the solid state it has a metallic lustre, a steel-blue colour, and a sonorous, metallic ring.

6—It differs from the metals in these points:—

(1) Its compounds with the Non-metals are partly acid and partly basic.

Compare  $\text{HCl}$  with  $\text{NH}_3$ .

(2) Its normal physical condition is gaseous.

7—The points of agreement far out-weigh the points of difference. For many metals form compounds with the non-metal Oxygen, some of which are *Acid*. And, finally, though metals, as a class, are heavy solids, yet Mercury is liquid. May not Hydrogen, then, be the *gaseous* form of a metal *Hydrogenium*?

## The Halogens.

Chlorine	=	35.5
Bromine	=	80
Iodine	=	127
Fluorine	=	19

1—These Elements are classed together because they agree in the following points:—

(1) They are monads.

(2) Their Hydrogen compounds are powerful acids.





(3) Their binary Hydrogen compounds contain equal volumes of the constituent gases united without condensation.

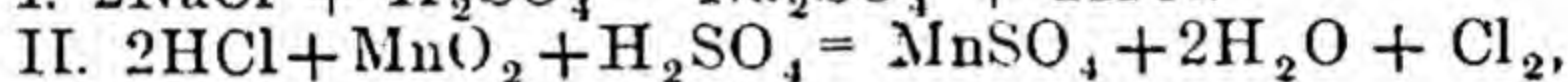
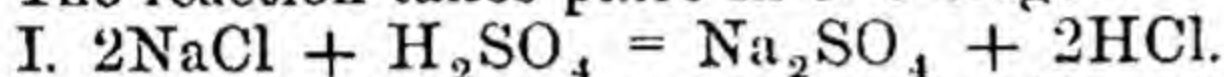
2 The group is called the Halogen group, because the first three members are of marine origin.

## Chlorine, $\text{Cl}' = 35.5$ .

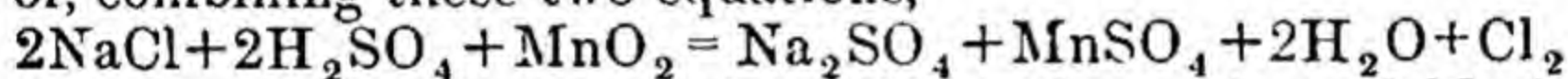
1—*Source*. Sodid Chloride.  $\text{NaCl}$ .

2—*Preparation*. (1) By heating Sodid Chloride with Sulphuric Acid ( $\text{H}_2\text{SO}_4$ ) and the black Oxide of Manganese.

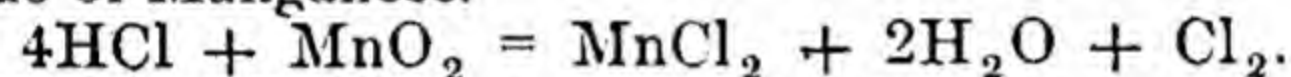
The reaction takes place in two stages.



or, combining these two equations,



(2) From Hydrochloric Acid by the action of black Oxide of Manganese.

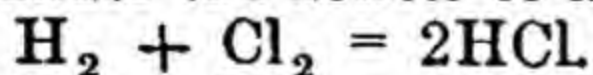


3—*Physical Properties*.

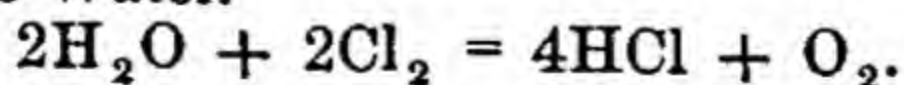
Yellow Gas. Characteristic odour. It is 2.5 times as heavy as air. Collected by downward displacement. Water dissolves upwards of twice its own volume of Chlorine at  $15^\circ\text{C}$  forming Chlorine Water. At  $0^\circ\text{C}$  crystals having the composition  $\text{Cl}_2, 10\text{H}_2\text{O}$  form.

(1) Combines *directly* with all Elements except Fluorine, Oxygen, Nitrogen, and Carbon, with some of which, however, it combines *indirectly*.

(2) A mixture of equal volumes of Hydrogen and Chlorine explodes under the action of light.



(3) When Chlorine Water is exposed to light, the Chlorine, by its great affinity for Hydrogen, displaces the Oxygen of the Water.







Hence Chlorine is a powerful *indirect* oxidiser.

(4) Owing to its indirect oxidising power it bleaches moist vegetable colours. It bleaches because it liberates Oxygen from the moisture and the nascent Oxygen acts on the colouring matter.

(5) Hydrocarbons burn in Chlorine, some, such as Turpentine, igniting spontaneously. The products of combustion are Carbon and Hydrochloric Acid.

(6) Powdered Antimony and Dutch Metal ignite spontaneously in Chlorine, forming Metallic Chlorides.

(7) Phosphorus burns in Chlorine, forming  $\text{PCl}_3$ , and in Chlorine if excess be in contact with  $\text{PCl}_3$ , then  $\text{PCl}_5$  is formed.

#### 5—Tests.

(1) Odour.

(2) Colour—greenish yellow.

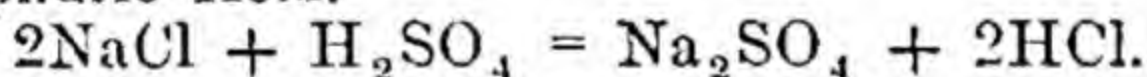
(3) Bleaching power.

(4) Liberates Iodine from Potassic Iodide.

### Hydrochloric Acid, $\text{HCl}$ .

1—Source, Sodie Chloride,  $\text{NaCl}$ .

2—Preparation. (1) By distilling Sodie Chloride with Sulphuric Acid.

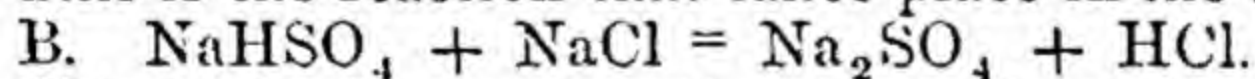


The reaction takes place in two stages.

A. At a low temperature.



This is the reaction that takes place in the laboratory.

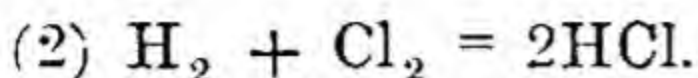


This is the further reaction that takes place at a high temperature in the manufacture of Hydrochloric Acid on the large scale.

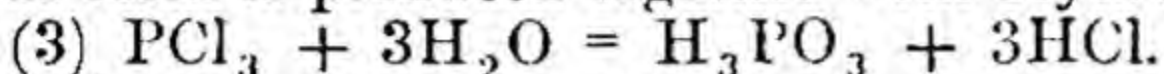
The above is the usual method for preparing Hydrochloric Acid.

The following methods have a theoretical importance :—

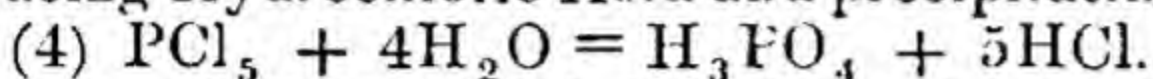




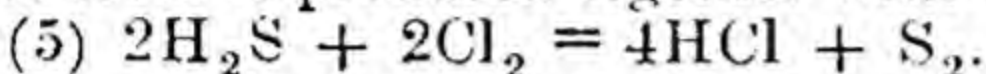
When Water is added to Phosphorus Chloride, Phosphorus Acid is produced together with Hydrochloric Acid.



Chlorine unites with the Hydrogen of Hydric Sulphide, producing Hydrochloric Acid and precipitating the Sulphur.

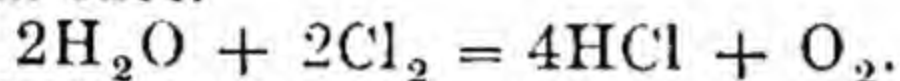


When Water is added to Phosphoric Chloride, Phosphoric Acid is produced together with Hydrochloric Acid.



The noxious effect of either gas may thus be counteracted by the other.

6. By passing Steam and Chlorine through a red hot porcelain tube.

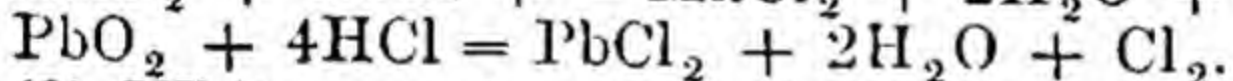
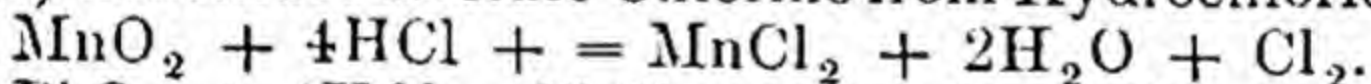


### 3—Physical Properties.

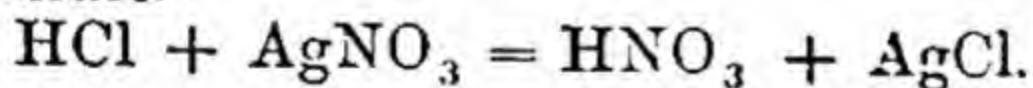
Colourless gas, fuming in *moist* air. One volume of Water at 0°C dissolves 500 volumes of Hydrochloric Acid Gas. Hence the gas is collected *in* water. The Hydrochloric Acid of Commerce is a solution of gas in water.

### 4—Chemical Properties.

(1) Bin oxides liberate Chlorine from Hydrochloric Acid.



(2) White precipitate of Silver Chloride with Argentic Nitrate.



### 5—Tests.

(1) White precipitate with Silver Nitrate, insoluble in Nitric Acid, but soluble in Ammonia.

(2) Disengagement of Chlorine gas by the action of Black Oxide of Manganese and Sulphuric Acid.

(3) If a Chloride be boiled with Potassium Dichromate and Sulphuric Acid, a deep brownish red gas ( $\text{CrO}_2\text{Cl}_2$ ) comes off. The gas will cause a yellow precipitate of Plumbic Iodide on a rod moistened with Plumbic Acetate.





### 6--*Proof of Composition.*

We have now to prove that HCl is the correct formula for Hydrochloric Acid.

#### I.—Synthetically.

(1) Equal volumes of Hydrogen and Chlorine exploded in a Eudiometer produce a volume of Hydrochloric Acid equal to the sum of the equal volumes exploded.

#### II. Analytically.

(1) By electrolysis—using a Carbon electrode where the current enters.

2. By decomposing the gas by a pellet of Sodium.

Sodium combines with the Chlorine. The Hydrogen left occupies just half the original volume taken.

Now we know from the density of the gas that 22.4 litres of it weigh 36.5 grammes. Subtract the weight of the half-vol. of Hydrogen (11.2 litres) that it contains. Then we have  $36.5 - 11.2 = 25.3$  grammes.

This is the weight of 11.2 litres of Chlorine.

Therefore 22.4 litres of Hydrochloric Acid gas are made up of 11.2 litres of Hydrogen, and 11.2 litres of Chlorine.

3—We may proceed directly from the density compared with air, thus:—

$$\begin{array}{rcl} \text{Density of HCl} & = & 1.25 \\ \text{Subtract } \frac{1}{2} \text{ density of H} & = & .035 \\ \hline \end{array}$$

The remainder 1.215 is half the density of Chlorine. Therefore, half-a-volume of Hydrogen, together with half-a-volume of Chlorine, yield 1 vol. of Hydrochloric Acid. Two volumes of Hydrochloric Acid contain 1 volume of Hydrogen and 1 volume of Chlorine.

4—To find percentage composition.

$$\begin{array}{rclcl} \text{Density of Hydro-} & : & \frac{1}{2} \text{ density of} & : & : \text{HCl} : : \text{Cl} \\ \text{chloric Acid} & : & \text{Chlorine} & : & : \\ 1.25 & : & 1.215 & : & : 100 \quad 2.8 \end{array}$$





Density of Hydrochloric Acid	:	$\frac{1}{2}$ density of Hydrogen	:	:	HCl	:	:	H
1.25	:	.035	:	:	100	:	:	2.8

∴—To find the correct formula—

Percentage of H	=	2.8	now	$2.8 \div 1 = 2.8$ .
" Cl	=	97.2	now	$97.2 \div 35.5 = 2.8$ .
∴ H : Cl	:	:	2.8	: 2.8.
	:	:	1	: 1.

The formula is HCl.

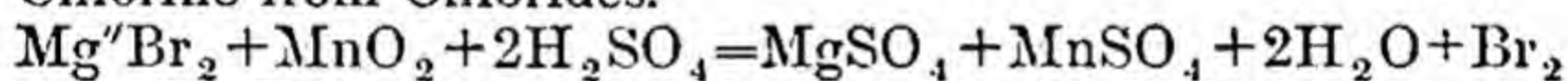
## Bromine, Br' = 80.

### 1—Sources.

Sea Water, Marine Plants, and Saline Springs.

### 2—Preparation.

(A) From Bromides by the method for preparing Chlorine from Chlorides.



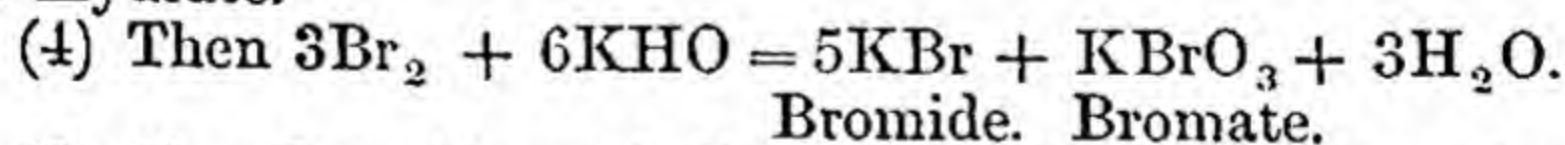
(B) From concentrated sea-water by Balard's process.

(1) Pass Chlorine through the solution to liberate the Bromine.



(2) Agitate the solution with Ether. On settling, there will be a supernatant red-coloured solution of Bromine in Ether.

(3) Siphon the solution off into a solution of Potassium Hydrate.



(5) The Bromide and Bromate crystallize out. On heating, the Bromate loses its Oxygen, and is reduced to Bromide.



(C) From Potassic Bromide, Bromine is prepared by the process (A) described above.

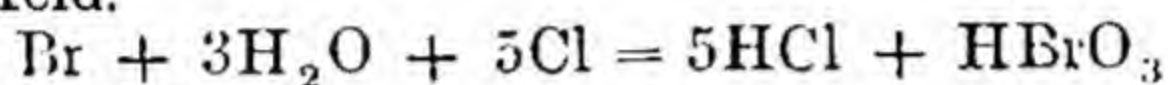


### 3—*Physical Properties.*

A very volatile red liquid, with characteristic odour. Boils at  $63^{\circ}\text{C}$ . Very slightly soluble in Water. Very soluble in Ether, Chloroform, and Carbon Disulphide.

### 4—*Chemical Properties.*

Analogous to the properties of Chlorine. It bleaches—liberates Oxygen from Water. Forms the crystalline compound  $\text{Br}_2 \cdot 10\text{H}_2\text{O}$  analogous to  $\text{Cl}_2 \cdot 10\text{H}_2\text{O}$ . Antimony and Arsenic burn in Bromine vapour, forming Bromides of Antimony and of Arsenic. Chlorine acts on Bromine Water forming Hydrogen Bromate and Hydrochloric Acid.



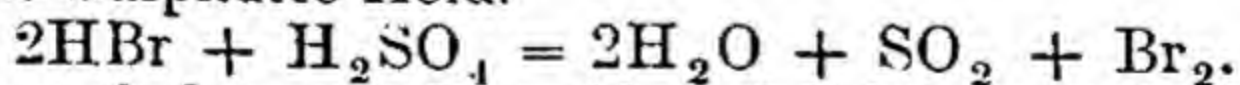
### 5—*Tests for Bromine.*

- (1) Its colour.
- (2) Its odour.
- (3) Its bleaching power.
- (4) Products of Hydrobromic Acid by Hydric Sulphide.  $\text{Br} + \text{H}_2\text{S} = 2\text{HBr} + \text{S}$ .
- (5) Gives a yellowish white precipitate with Nitrate of Silver.

## Hydrobromic Acid, $\text{HBr}$ .

### 1—*Preparation.*

It is to be carefully noted that Hydrobromic Acid cannot be prepared by the method usually adopted for the preparation of Hydrochloric Acid. When *Chlorides* are heated with Sulphuric Acid, Hydrochloric Acid distils over. But when *Bromides* are heated with Sulphuric Acid, the first portion of Hydrobromic Acid produced decomposes the Sulphuric Acid.



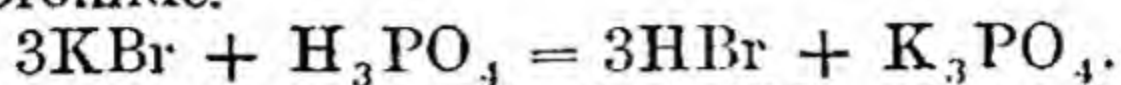
Nevertheless, the Bromides of Calcium and of Barium if treated with very dilute Sulphuric will yield a solution of Hydrobromic Acid.





2—The following are the methods usually adopted:—

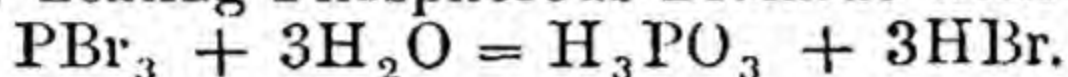
(1) By distilling a mixture of Phosphoric Acid with Potassic Bromide.



(2) By passing Hydric Sulphide through Bromine Water.



(3) By heating Phosphorous Bromide with Water.



## 2—Physical Properties.

A colourless gas, very soluble in Water.

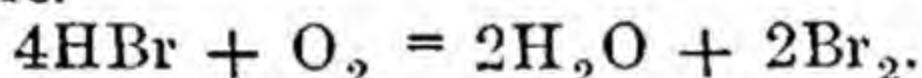
## 3—Chemical Properties.

(1) The Bromine of Bromides is readily displaced by Chlorine.



(2) The Bromides of Silver, Mercury, and Lead are insoluble.

(3) Hydrobromic Acid is decomposed by exposure to the atmosphere.



## 4—Tests for Bromides.

(1) Characteristic vapours with  $\text{H}_2\text{SO}_4$  and  $\text{MnO}_2$ .

(2) On treating Bromides with Chlorine Water followed by Ether, a red solution appears at the top.

(3) Argentic Nitrate gives a yellowish white precipitate of  $\text{AgBr}$ , insoluble in Nitric Acid, but rather soluble in Ammonia.

## 5—Proof of composition.

By heating a pellet of Potassium in a bent tube filled with Hydrobromic Acid vapour, it is found that after the reaction half the volume of gas remains, and this half-volume is Hydrogen. From this experiment the composition is deduced by the method for Chlorine already set forth.





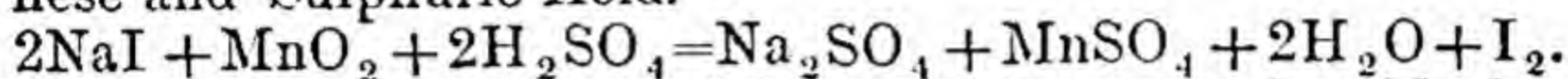
## Iodine I = 127.

### 1—*Source.*

Sea Water, Saline Springs, and especially Sea Weeds.

### 2—*Preparation.*

(1) The ash of Sea Weeds is lixiviated. Carbonates and Chlorides crystallize out. The mother liquid, containing Sodid Iodide, is treated with Black Oxide of Manganese and Sulphuric Acid.



(2) Iodine is liberated from Iodides by both Chlorine and Bromine.



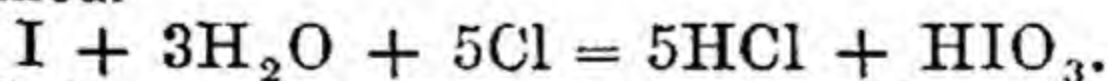
### 3—*Physical Properties.*

A steel blue volatile solid with metallic lustre. It has a characteristic odour, and stains the skin yellow. It fuses at  $107^\circ\text{C}$ , and boils about  $200^\circ\text{C}$ , yielding characteristic violet vapour. Scarcely soluble in Water, forms no crystalline Hydrates analogous to  $\text{Cl}_2 \cdot 10\text{H}_2\text{O}$  and  $\text{Br}_2 \cdot 10\text{H}_2\text{O}$ . Very soluble in Potassic Iodide, Chloroform and Alcohol.

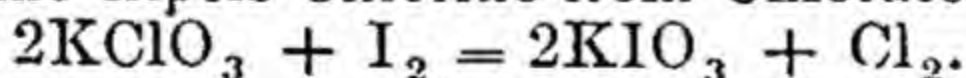
### 4—*Chemical Properties.*

These are analogous to the properties of Chlorine and Bromine, but are feebler.

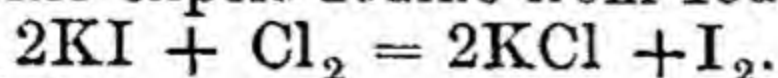
(1) Chlorine will cause Iodine suspended in Water to be oxidised—Hydrogen Iodate and Hydrochloric Acid being formed.



(2) Iodine expels Chlorine from Chlorates.



(3) Chlorine expels Iodine from Iodides.



### 5—*Tests for Iodine.*

(1) Its violet vapour.

(2) Steel blue scales condensed from the vapour.



(3) Its solution colours a solution of starch blue. The colour disappears on heating.

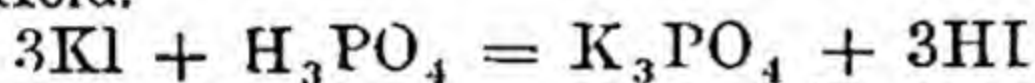
(4) Gives a yellowish precipitate with Nitrate of Silver.

## Hydriodic Acid, HI.

### 1—*Preparation*

(1) As Hydrobromic Acid cannot be prepared by distilling Sulphuric Acid with Bromides, neither can Hydriodic Acid be prepared by distilling Sulphuric Acid with Iodides.

(2) The methods for preparing Hydriodic Acid are precisely analogous to the methods for preparing Hydrobromic Acid.

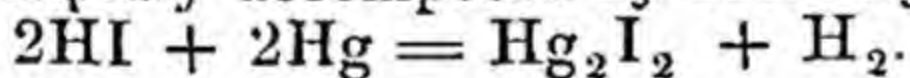


### 2—*Physical Properties.*

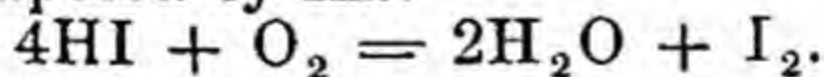
A heavy, colourless gas, very soluble in water. Dissociated by heat or by spongy Platinum.

### 3—*Chemical Properties.*

(1) It is rapidly decomposed by Mercury.



(2) Decomposed by Air.



### 3—*Tests for Iodides.*

(1) The Iodides of Silver and Lead, as also Mercurous and Cuprous Iodides, are insoluble.

(2) Acids cause an evolution of violet or purple vapour.

(3) Iodides, when treated with Chlorine Water followed by Chloroform, yield a purple solution.

(4) Iodides, when treated with Chlorine Water, followed by Starch solution, yield an intensely blue coloration.





(5) Silver Nitrate gives a yellow precipitate of Silver Iodide, insoluble both in Ammonia and Nitric Acid.

(6) Mercuric Chloride gives a precipitate of Mercuric Iodide, rapidly changing from light yellow to deep scarlet. The precipitate is soluble in excess of either re-agent. This last test distinguishes Iodides from Chlorides and Bromides.

## Fluorine F, = 19.

1—This element has not been isolated. Its existence is inferred from the analogy of the existing Acid—Hydrofluoric Acid—to Hydrochloric and to Hydrobromic Acid. The Fluorides are isomorphous with the Chlorides, Bromides, and Iodides.

2—From the percentage composition of the compounds we can deduce the Atomic weight of the element.

One hundred grammes of Calcic Fluoride gave, when heated, 174.5 grammes of Calcic Sulphate,  $\text{CaSO}_4$ .

The molecular weight of  $\text{CaSO}_4$  is 135, and this weight contains 40 of Calcium.

Now, the Calcium contained in 174.5 grammes of  $\text{CaSO}_4$  is the amount of Calcium contained in 100 grammes of Calcic Fluoride. This amount can be calculated by the following proportion:—

$$136 : 40 :: 174.5 : x = 51.27.$$

Therefore, the quantity of Fluorine in 100 grammes must be

$$100 - 51.27 = 48.73.$$

From the percentage composition we can calculate the amount of Fluorine combined with 40 of Calcium.

$$51.27 : 40 :: 48.73 : x = 38.01, \text{ or } 38 \text{ nearly.}$$

But 40 of Calcium is the equivalent of 2 of Hydrogen, 2 of Chlorine, or 2 of Bromine, and, therefore, of 2 of Fluorine. Therefore, the Atomic weight of Fluorine is 19.



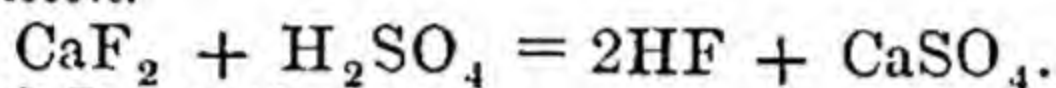
3—The Atomic weight may also be deduced from the specific gravity compared with Hydrogen which is 10. Therefore the molecular weight is 20. Now, if Hydrofluoric Acid is analogous to Hydrochloric Acid, and Hydriodic Acid, this molecular weight contains an atom of Hydrogen. Therefore the Atomic weight of Fluorine must be  $20 - 1 = 19$ .

## Hydrofluoric Acid.

### 1—Source.

Fluor Spar, which is Calcic Fluoride,  $\text{CaF}_2$ , and Cryolite, which is Sodid Aluminiic Fluoride.  $6\text{NaF}, \text{Al}_2\text{F}_6$ .

### 2—Preparation.



### 3—Physical Properties.

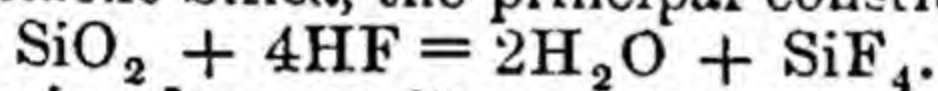
A colourless fuming gas having caustic action on the skin.

### 4—Chemical Properties.

(1) Combines with Water in definite proportions with great evolution of heat.

(2) Attacks all metals except Gold, Silver, and Platinum, and acts but very slightly on Lead.

(3) It attacks Silica, the principal constituent of glass.



(4) Chlorine does not liberate Fluorine from solutions of its compounds.

### 5—Tests for Fluorides.

(1) When treated with Sulphuric Acid they yield a gas which etches glass.

(2) They differ from the Chlorides, Bromides and Iodides in giving no precipitate with Argentic Nitrate. Argentic Fluoride is soluble.

### 4—Proof of Composition.

(1) By measuring the volume of Hydrogen needed to combine with the Fluorine in a given weight of Argentic Fluoride.





(2) The density of gaseous Anhydrous Hydrofluoric Acid is ten times the density of Hydrogen.

(3) The Fluorides are isomorphous with the Halogen Salts.

## Dyads.

Oxygen	O''	16.
Sulphur	S''	32.

1—These elements are classed together on account of their dyad valency, and the general analogy of their compounds. This analogy is shown in the following table:—

Oxygen.		Sulphur.	
H <sub>2</sub> O	Hydric Sulphide	H <sub>2</sub> S	Hydric Sulphide
KHO	Pot. Hydrate	KHS	Pot. Sulphydrate
K <sub>2</sub> O	Pot. Oxide	K <sub>2</sub> S	Pot. Sulphide
K <sub>2</sub> CO <sub>3</sub>	Pot. Carbonate	K <sub>2</sub> CS <sub>3</sub>	Pot. Sulphocarbonate
CO <sub>2</sub>	Carbonic Dioxide	CS <sub>2</sub>	Carbonic Disulphide

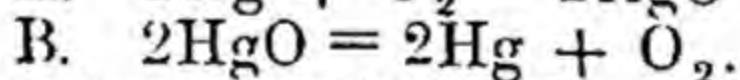
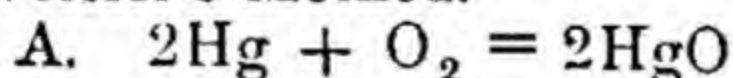
## Oxygen O' 16.

Air, Water, Oxides, Chlorates, and Nitrates. One fifth of the atmosphere by volume, and eight ninths of the weight of Water is Oxygen.

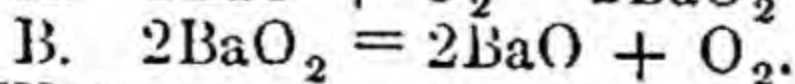
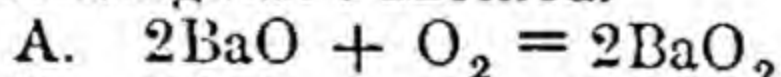
### 2—Preparation.

#### I. From Air.

##### (1) Lavoisier's Method.



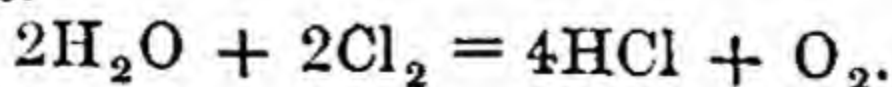
##### (2) Boussingault's Method.



#### II. From Water.

##### (1) By electrolysing.

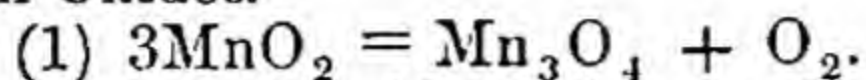
(2) By passing steam and Chlorine through a red hot porcelain tube.



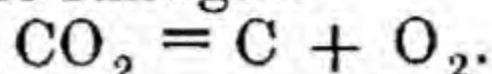




## III. From Oxides.

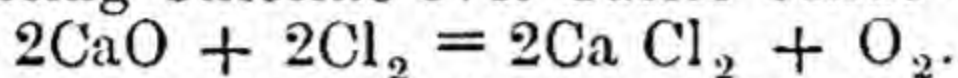


(2) From Carbonic Acid in Air, or, for experimental purposes, better in Water, by the green leaves of plants under the influence of sunlight.

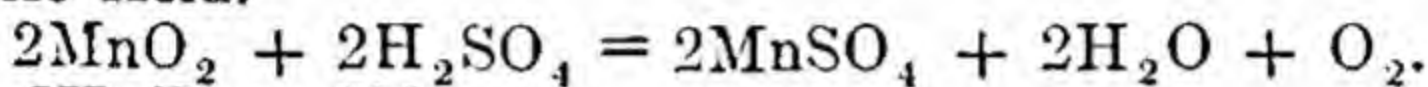


The Carbon is fixed by the plant for its nutrition.

(3) Passing Chlorine over Calcic Oxide in a hot tube.

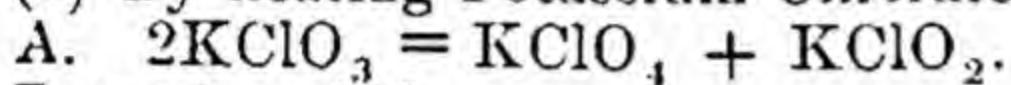


(4) By treating Black Oxide of Manganese with Sulphuric Acid.

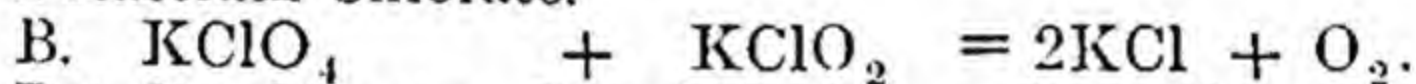


## IV. From Chlorates.

(1) By heating Potassium Chlorate.



Potassium Chlorate.



Pot Perchlorate. Pot. Chlorite. Pot. Chloride.

The second reaction takes place at a higher temperature than the first. Potassium Chlorate will yield all its Oxygen at once, being reduced to KCl, without the formation of immediate compounds by the addition of its own weight of Black Oxide of Manganese, or of Ferric Oxide, or about the sixth of its weight of Cupric Oxide. These bodies undergo no change. They promote the decomposition of the Potassic Chlorate. This action is called Catalysis.

3—*Physical Properties.*

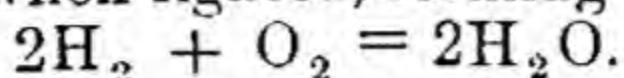
Colourless, odourless, tasteless gas, of the lowest refractive power. Under normal conditions Water dissolves from three to four per cent. of its own volume of Oxygen. Liquified at  $-140^\circ\text{C}$ , under a pressure of 320 atmospheres. It is magnetic and electro-negative.

4—*Chemical Properties.*

(1) Does not combine directly with any of the Halogens, while with Fluorine it does not combine at all.



(2) A mixture of 2 vols. of Hydrogen and one of Oxygen explodes when lighted, forming steam.



(3)  $\text{Fe}_3 + 2\text{O}_2 = \text{Fe}_3\text{O}_4$  = Magnetic Oxide of Iron.

(4)  $2\text{Zn} + \text{O}_2 = 2\text{ZnO}$  = Zinc Oxide.

(5)  $\text{S} + \text{O}_2 = \text{SO}_2$  = Sulphurous Anhydride.

(6)  $\text{C} + \text{O}_2 = \text{CO}_2$  = Carbonic Anhydride.

(7)  $\text{P}_4 + 5\text{O}_2 = 2\text{P}_2\text{O}_5$  = Phosphoric Anhydride.

#### 5—Tests for Oxygen.

(1) A glowing splinter kindles up brilliantly in Oxygen gas.

(2) Turns Pyrogallate of Potash brown.

(3) Gives red fumes with Nitric Oxide.

### Ozone = $\text{O}_3$ 48.

1—Ozone is allotropic Oxygen.

#### 2—Preparation.

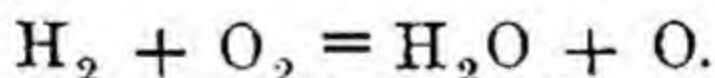
(1) By electrical discharges in Oxygen.

(2) By the slow oxidation of Phosphorus in moist air.

(3) By oxidising Ether vapour with a hot glass rod.

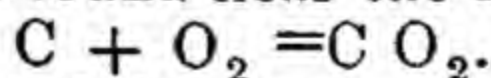
(4) When Hydrogen burns in air Ozone is found in the neighbourhood of the flame.

When Hydrogen burns it breaks up the molecule of Oxygen, thus:—



This simple atom of O thus liberated, at once combines with the molecule  $\text{O}_2$ , which is Ozone.

When a body such as Carbon, which takes a complete molecule of Oxygen for its complete combustion, is burning, no Ozone is found near the flame.



No single atom is left unpaired in the reaction, and, therefore, there is no Ozone.





### 3—Physical Properties.

A colourless gas, with characteristic smell and taste. At a temperature of upwards of  $100^{\circ}\text{C}$ , it dissociates, forming ordinary Oxygen.

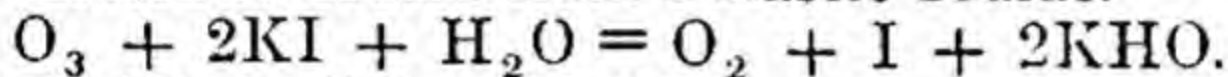
Ozone is readily absorbed by essential oils, such as Turpentine.

### 4—Chemical Properties.

(1) Most prominent are its oxidising and bleaching powers.

(2) The Halogens, which do not unite directly with Oxygen, unite with Ozone.

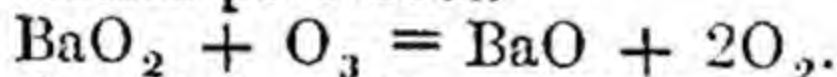
(3) Liberates Iodine from Potassic Iodide.



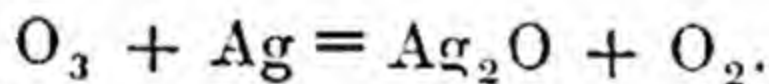
(4) Oxidises  $\text{PbS}$  to  $\text{PbSO}_4$ .

(5) Converts Ferrous Salts into Ferric Salts.

(6) It deoxidises peroxides.



(7) It is de-oxidised by finely divided Charcoal or Silver.



### 5—Tests for Ozone.

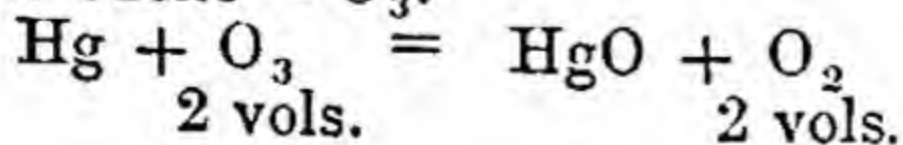
(1) Odour.

(2) Turns Starch paper, moistened with Potassic Iodide, blue, owing to the liberation of Iodine.

### 6—Proof of Composition.

(1) The density of Ozone compared with Hydrogen has been deduced from observations on its rate of diffusion. The density thus observed is nearly 24. The molecular weight would therefore be 48, and the molecule of Ozone would contain three atoms of Oxygen, each weighing 16.

(2) When Mercury is agitated in Ozone, the Mercury is oxidised, and a volume of Oxygen is produced equal to the volume of the Ozone acted upon. This is explicable if we assume that  $\text{Ozone} = \text{O}_3$ .





This result is confirmed by the fact that, when Ozone is expelled from solution and heated to  $300^{\circ}$ , is then found to be ordinary Oxygen, and the volume of it is half as great again as the volume of Ozone originally dissolved.

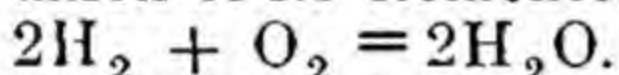
## Compounds of Hydrogen with Oxygen.

$H_2O$  Hydric Oxide, Water.  
 $H_2O_2$  Hydric Peroxide.

Water  $H_2O$  18.

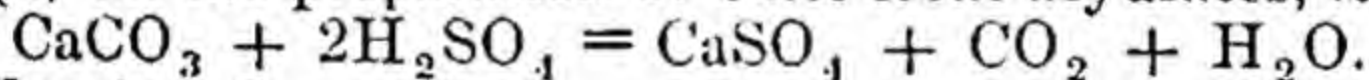
### 1—Preparation.

(1) By direct union of its elements.



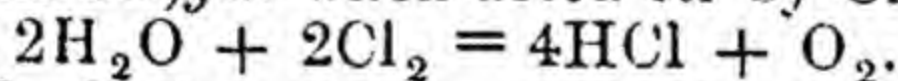
When 2 parts by weight of Hydrogen unite with 16 parts by weight of Oxygen, the quantity of heat evolved is sufficient to heat 68,924 parts by weight of Water from  $0^{\circ}$  to  $1^{\circ}$ , no matter at what rate the combustion takes place.

(2) In the preparation of Salts from Hydrates, &c.

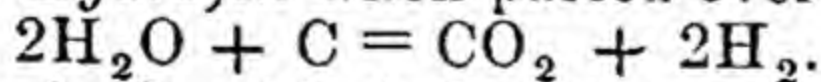


### 2—Chemical Properties.

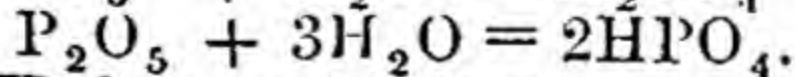
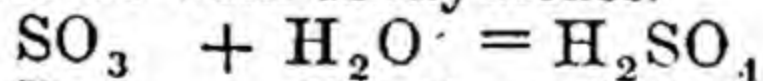
(1) Yields *Oxygen* when acted on by Chlorine.



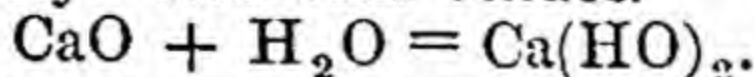
(2) Yields *Hydrogen* when passed over red-hot coke.



(3) Forms Acids with Anhydrides.



(4) Forms Hydrates with Oxides.



Water thus contained in Acids and Hydrates is called *Water of Constitution*.



(5) Many bodies when they crystallize take up Water in the formation of the Crystals. *e.g.*,  $\text{Cl}_2 \cdot 10\text{H}_2\text{O}$ ,  
 $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ ,  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$   
 $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ,  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

(6) Certain bodies readily absorb moisture, and are used in the Laboratory as dessicators or dryers, *e.g.*,  
 Sulphuric Acid      Dry Potash or Soda  
 Calcium Chloride    Calcium Oxide

### 3—*Purification of Water.*

Ordinary Water is charged with the gases of the atmosphere. It carries in suspension and in solution many earthy impurities. Gases can be removed by boiling. Solids in suspension can be removed by filtration. Solids in solution must be precipitated by suitable chemical reagents. Water can be thoroughly purified by distillation. Distilled Water should leave no residue on evaporation. The principal soluble impurities in ordinary Water are:—Carbonic Acid, Carbonates, Sulphates, and Chlorides of Calcium. Lead and Copper may be present from contact with pipes and vessels of these metals.

Table for the detection of Common Impurities:—

Reagents	Precipitates or other Results	Indicate the Presence of
$\text{Ca}(\text{HO})_2$	White ppt	Carbonic Acid
Ammonium Oxalate	White ppt	Lime $\text{CaO}$
$\text{BaCl}_2 + \text{HCl}$	White ppt	Sulphates
$\text{AgNO}_3 + \text{HNO}_3$	White ppt	Chlorides
Potassium Permanganate (Condy's Fluid)	Decolourised	Organic Matter





#### 4—Softening of Water.

(1) Water containing Carbonates or Sulphates is called *hard*. Hardness due to Carbonates is called *temporary*, because it is removed by boiling. Hardness due to Sulphates is called *permanent*, because it can be removed only by Chemical reagents.

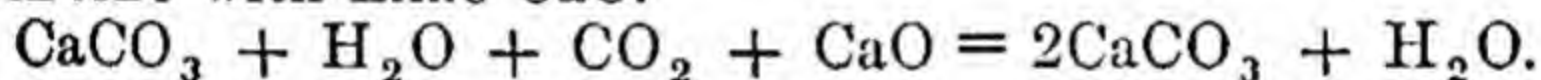
(2) Temporary hardness.

(a) Calcic Carbonate is insoluble in pure water. It is soluble in water containing Carbonic Acid. Carbonic Acid is a gas. If the Water is boiled the gas goes off, and the Calcic Carbonate, no longer in solution, settles down from suspension, causing a "fur" on the boiler.

Its normal Salt,  $\text{CaCO}_3$ , is insoluble. It is the Acid Salt,  $\text{CaH}_2(\text{CO}_3)_2$ , that is soluble. But this Acid Salt is decomposed on heating the solution, the normal insoluble Salt being formed.

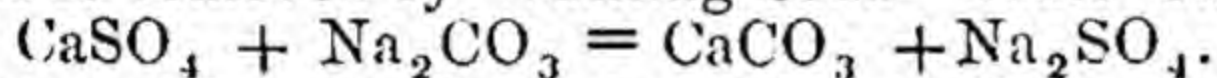
(b) Clark's Method.

The free Carbonic Acid is removed by causing it to combine with Lime  $\text{CaO}$ .



#### 3—Permanent Hardness.

This is removed by Washing Soda—Sodic Carbonate.



The resulting  $\text{CaCO}_3$  is insoluble in Water, and Sodic Sulphate does not cause hardness.

#### 5—Proof of Composition.

(A) By volume.

(1) Analytically. By electrolysing Water.

(2) By exploding Hydrogen and Oxygen in an Eudiometer.

Into an Eudiometer are passed 100 measures of Oxygen and 100 measures of Hydrogen. The mixed gases are exploded over Mercury. After the explosion, the residual gas is found to be 50 measures of Oxygen, the Mercury having risen through 150 measures.



This shows that 100 measures of Hydrogen have united with 50 measures of Oxygen to form Water.

B. By weight.

By passing pure dry Oxygen over Cupric Oxide in a hot tube.



Two observations are made. (1) The loss of weight of the Cupric Oxide. (2) The weight of Water produced. The first measures the Oxygen, and, by subtracting it from the second, we get the weight of Hydrogen. Thus we know what weight of Hydrogen and of Oxygen make up the observed weight of Water.

2—From the following observations it is required to deduce the percentage composition and the formula of Water:—

Weight of tube & Oxide before experiment	334.598	grms.
Weight of tube & Oxide after experiment	314.236	"
Weight of drying tubes before experiment	426.358	"
Weight of drying tubes after experiment	449.263	"
$334.598 - 314.236 = 20.362 = \text{weight of Oxygen.}$		
$449.263 - 426.358 = 22.905 = \text{weight of Water.}$		
Weight of Water—weight of Oxygen = weight of Hydrogen		
$22.905$	$20.362$	$= 2.543.$
$22.905 : 2.543$	$:$	$100 : x = 11.11$
$22.905 : 20.362$	$:$	$100 : x = 88.89$
$\text{H} = 11.11 \div 1 = 11.11 \text{ and } 11.11 \div 5.5 = 2$		
$\text{O} = 88.89 \div 16 = 5.5 \text{ and } 5.5 \div 5.5 = 1$		

Therefore the formula is  $\text{H}_2\text{O}$ .

6—Mechanical Mixtures are to be carefully distinguished from compounds. To make the difference clear, we shall here tabulate the points that distinguish a mixture of two volumes of Hydrogen with one volume of Oxygen from Steam.



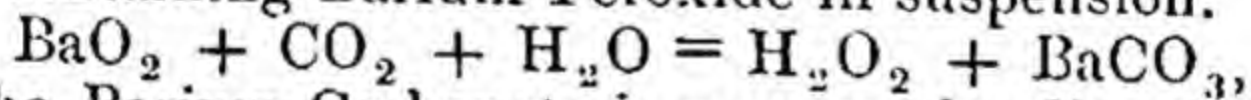


$H_2 + O.$	$H_2O.$
1.—Density $\frac{2 + 16}{3} = 6.$	1.—Density $\frac{18}{2} = 9.$
2.—On heating explodes forming steam.	2.—On heating expands, and on cooling contracts.
3.—Hydrogen rapidly diffuses out.	3.—Hydrogen does not diffuse as such. It goes combined with Oxygen as steam.
4.—Oxygen is readily absorbed by Pyrogallate of Potash.	4.—Does not part with Oxygen to this reagent.
5.—Is not absorbed by Hygroscopic bodies.	5.—Is readily absorbed.
6.—Condensable only under extremely high pressure and low temperature.	6.—Easily condensible.
7.—Absorbs but little radiant heat.	7.—Absorbs much radiant heat.

## Hydric Peroxide, $H_2O_2 = 34.$

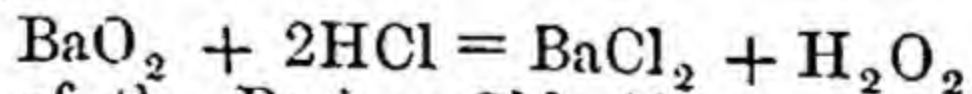
### 1.—*Preparation.*

(1) By passing a current of Carbonic Acid through Water containing Barium Peroxide in suspension.



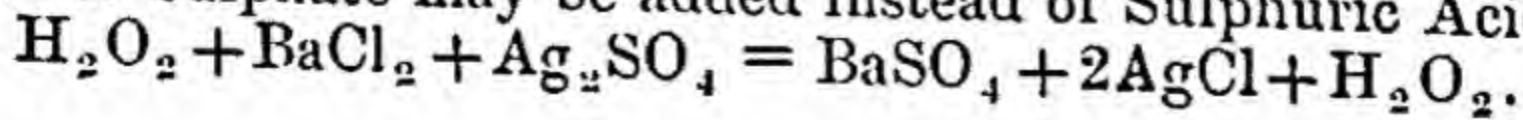
The Barium Carbonate is removed by filtration.

(2) By the action of Barium Peroxide on Hydrochloric Acid.



the Barium of the Barium Chloride can be precipitated as Sulphate by the addition of Sulphuric Acid, Hydrochloric Acid being regenerated in the process. This Hydrochloric Acid can act on a fresh portion of Barium Peroxide.

When sufficient Hydrogen Peroxide has been prepared, Silver Sulphate may be added instead of Sulphuric Acid.

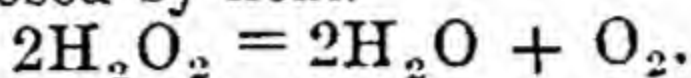




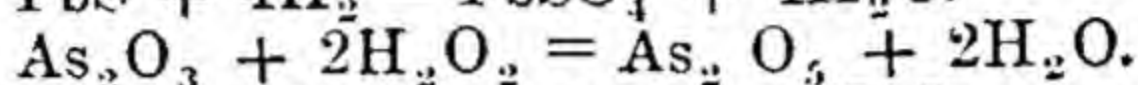
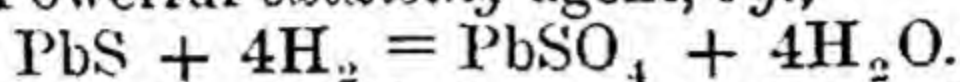
## 2—Physical Properties.

Colourless, syrupy liquid, soluble in Water.

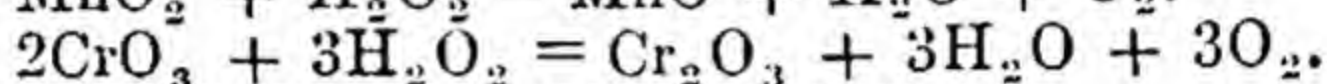
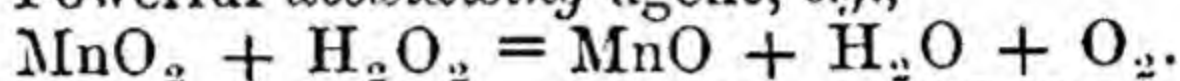
(1) Decomposed by heat.



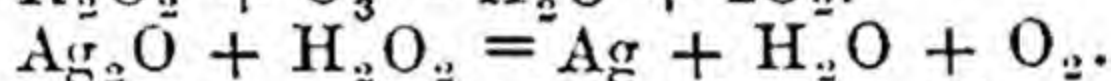
(2) Powerful *oxidising* agent, *e.g.*,



(3) Powerful *deoxidising* agent, *e.g.*,



Chromic Anhydride.                      Chromic Oxide.



(4) Decomposed catalytically by Platinum, Silver, Gold and Charcoal when finely divided.

## 4.—Tests.

(1) Chromic Acid gives a blue coloration, rendered more evident by the addition of ether.

(2) Permanganate of Potash is decolourised.

(3) Hydrogen Peroxide liberates Iodine from Potassium Iodide, which colours starch blue.

## 5—Proof of Composition.

A weighed portion of a concentrated Solution is heated. The residual Water is weighed, and the evolved Oxygen measured. When the volume has been expressed as weight, we know the weight of Oxygen and of Water that make up the portion of Hydrogen Peroxide in the Solution. Thenard found that at  $14^\circ\text{C}$  and 760mm pressure one volume of the concentrated liquid (Sp : gr : 1.4) yielded 475 volumes of Oxygen. This is not far different from the 501.8 volumes that would be evolved from a body having the composition indicated by the formula  $\text{H}_2\text{O}_2$ .



## Compounds of Chloride with Oxide.

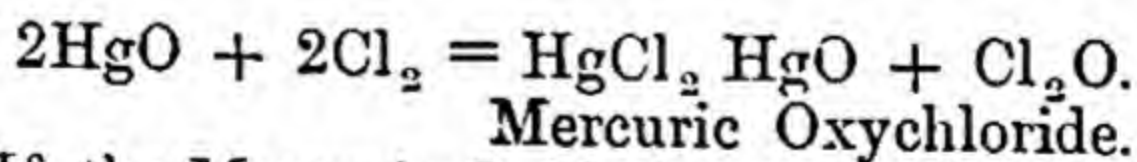
Oxides and Anhydrides.			Acid.
$\text{Cl}_2\text{O}$	=	Hypochlorous Anhydride	$\text{HClO}$
$(\text{Cl}_2\text{O}_2)?$	=	Chloric Oxide	—
$\text{Cl}_2\text{O}_3$	=	Chlorous Anhydride	$\text{HClO}_2$
$\text{Cl}_2\text{O}_4$	=	Perchloric Oxide	
$(\text{Cl}_2\text{O}_5)?$	=	Chloric Anhydride	$\text{HClO}_3$
$(\text{Cl}_2\text{O}_6)?$	=	Hyperchloric Oxide	—
$(\text{Cl}_2\text{O}_7)?$	=	Perchloric Anhydride	$\text{HClO}_4$

The compounds in brackets have not yet been prepared. Their existence is predicted from the numerical sequence of the series. It will be observed that though Perchloric Anhydride is not known, the corresponding Acid is well known.

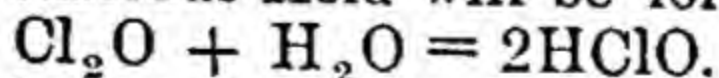
### Hypochlorous Anhydride, $\text{Cl}_2\text{O}$ .

#### 1—Preparation.

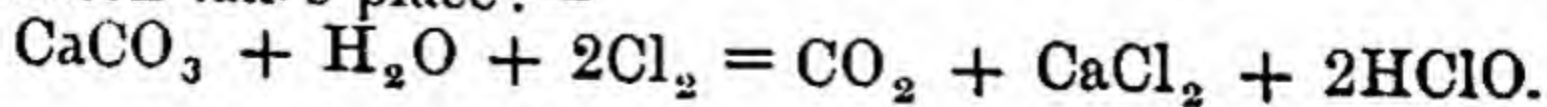
(1) By passing Chlorine over precipitated Mercuric Oxide.



(2) If the Mercuric Oxide is suspended in Water, a solution of Hypochlorous Acid will be formed.



(3) If Chlorine gas be passed through finely divided chalk suspended in a large bulk of Water, the following reaction takes place:—







(4) The Acid can be dehydrated by glacial Phosphoric Acid,  $\text{HPO}_3$ .

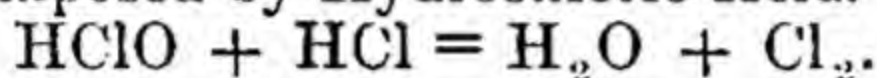


## 2—Physical Properties.

(1) The Anhydride is a yellow gas. The acid is a yellowish liquid.

## 3—Chemical Properties of Hypochlorous Acid.

(1) Decomposed by Hydrochloric Acid.



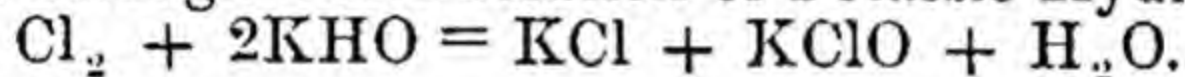
Hence its indirect oxidising power.

(2) Hypochlorites are formed by the addition of Hydrates.



Since the Hypochlorites readily yield Chlorine, they are important bleaching and oxidising agents.

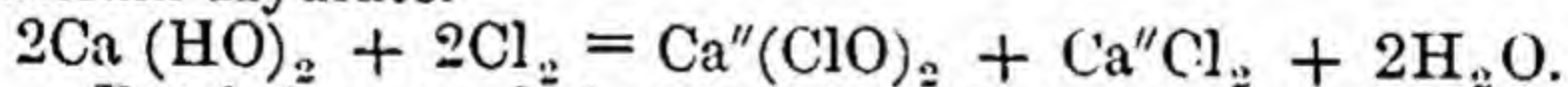
Potassium Hypochlorite is usually made by passing Chlorine through a cold solution of Potassic Hydrate.



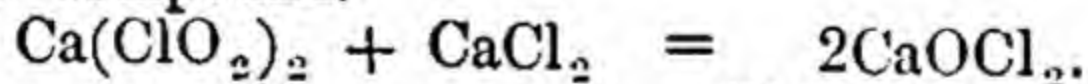
## Bleaching Powder.

The body is commonly called Chloride of Lime—that is the Chloride of Calcium Oxide and not of Calcium.

It is prepared by passing Chlorine Gas over trays of Calcium Hydrate.



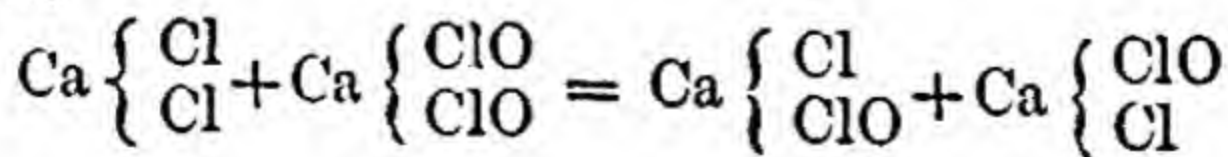
But it is proved that Calcic Chloride is not present in Chloride of Lime. The Hypochlorite and the Chloride form a new compound.



## Bleaching Powder.

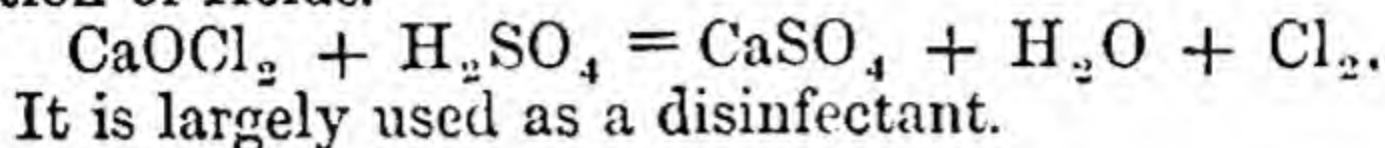
This compound may be regarded as Calcium Chloride with one atom of Chlorine replaced by an equivalent of the radicle  $\text{ClO}$ .

Thus





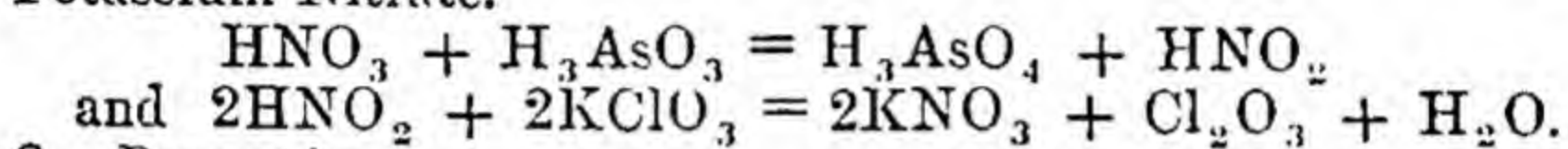
Bleaching Powder readily yields Chlorine on the addition of Acids.



## Chlorous Anhydride, $\text{Cl}_2\text{O}_3$ .

### 1—*Preparation.*

By heating gently a mixture Nitric and Arsenious Acids with Potassium Chlorate  $\text{KClO}_3$ . The Nitric Acid is reduced to Nitrous Acid by the Arsenious Acid. The Nitrous Acid deoxidises Potassium Chlorate, forming Potassium Nitrate.



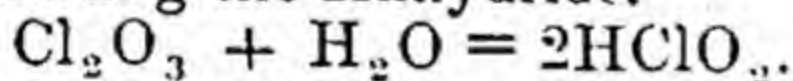
### 2—*Properties.*

A greenish yellow unstable explosive gas. Dangerous to prepare.

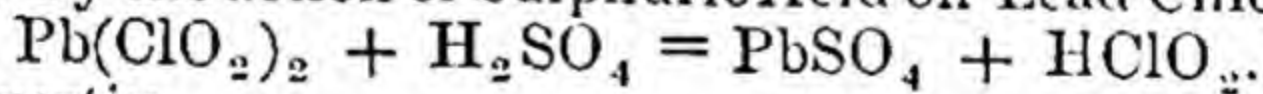
## Chlorous Acid, $\text{HClO}_2$ .

### 1—*Preparation.*

(1) By hydrating the Anhydride.



(2) By the action of Sulphuric Acid on Lead Chlorite.



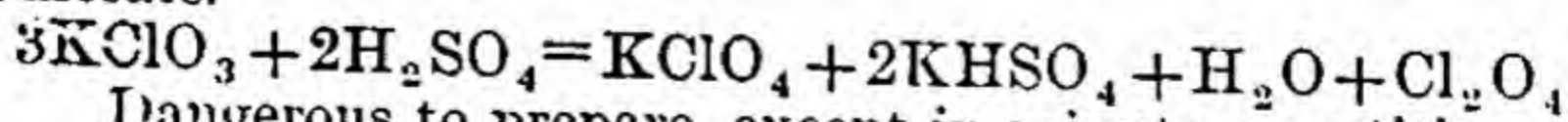
### 2—*Properties.*

A yellow liquid, feebly acid.

## Perchloric Oxide, $\text{Cl}_2\text{O}_4$ .

### 1—*Preparation.*

(1) By the action of Sulphuric Acid on Potassium Chlorate.



Dangerous to prepare, except in minute quantities.



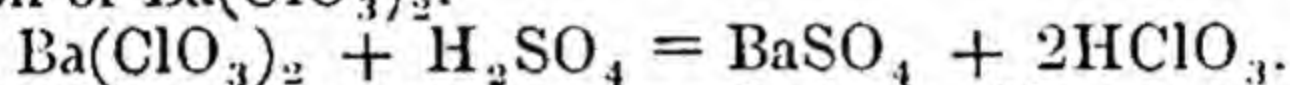


2—*Properties.*

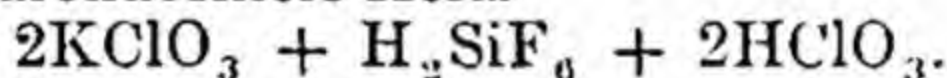
A yellowish gas, but, when prepared under water, the solution has a red colour. It is extremely explosive. When mixed with Carbon or Sulphur it deflagrates with brilliance. This may be demonstrated by the addition of Sulphuric Acid to a mixture of Potassic Chlorate and powdered Sugar.

Chloric Acid,  $\text{HClO}_3$ .1—*Preparation.*

(1) By adding Sulphuric Acid, drop by drop, to a solution of  $\text{Ba}(\text{ClO}_3)_2$ .



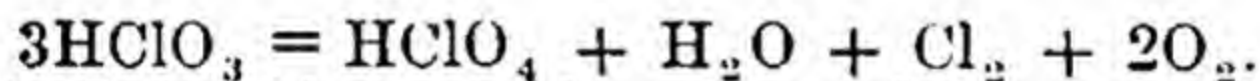
(2) By mixing two strong solutions of Potassium Chlorate and Hydrofluosilicic Acid.

2—*Physical Properties.*

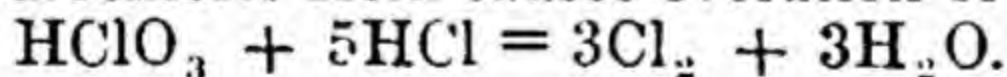
A colourless syrupy liquid, with very acid reaction.

3—*Chemical Properties.*

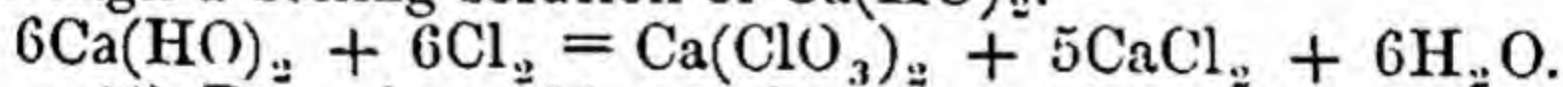
(1) When heated is converted into Hydrogen Perchlorate.



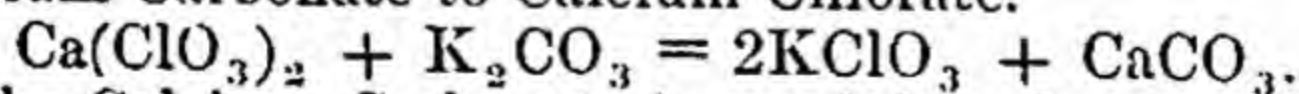
(2) Hydrochloric Acid causes evolution of Chlorine.

4—*Chlorates.*

(1) Calcium Chlorate is prepared by passing Chlorine through a boiling solution of  $\text{Ca}(\text{HO})_2$ .

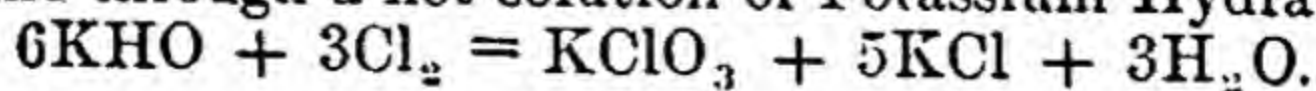


(2) Potassium Chlorate is prepared by adding  $\text{K}_2\text{CO}_3$ , Potassium Carbonate to Calcium Chlorate.



The Calcium Carbonate is precipitated.

(2) Potassium Chlorate can be made directly by passing Chlorine through a hot solution of Potassium Hydrate.





The less soluble Chlorate crystallizes out.

(4) The Chlorates evolve Oxygen on heating.

5—*Tests for Chlorates.*

(1) All soluble in Water.

(2) Deflagrate on Charcoal.

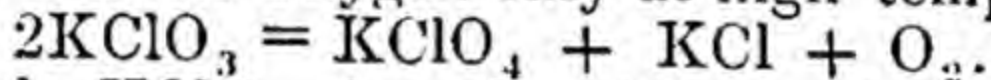
(3) Evolve Oxygen—the residue giving a white precipitate with Argentic Nitrate.

(4) A yellow explosive gas evolved on the addition of Sulphuric Acid.

## Perchloric Acid, $\text{HClO}_4$ .

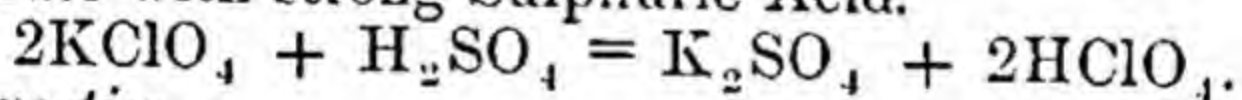
1—*Preparation.*

(1) Potassium Perchlorate is first prepared. When Potassium Chlorate is steadily and moderately heated, one-third of the Oxygen comes off, and then the evolution ceases. This check is owing to the formation of  $\text{KClO}_4$ , which parts with its Oxygen only at high temperatures.



The Salt,  $\text{KClO}_4$ , is only slightly soluble in Water, and, therefore, on digesting with Water the Potassic Chloride is separated.

(2) Perchloric Acid is prepared by distilling Potassium Perchlorate with strong Sulphuric Acid.

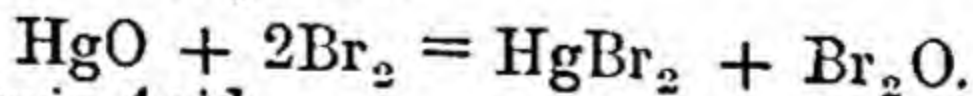


2—*Properties.*

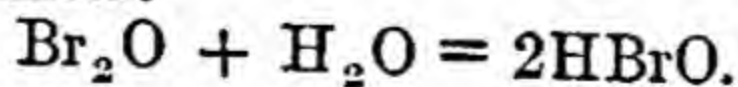
A colourless volatile liquid. Neither the Acids nor its salts are of any importance.

## Oxygen Compounds of Bromine.

1—*Hypobromic Anhydride.*

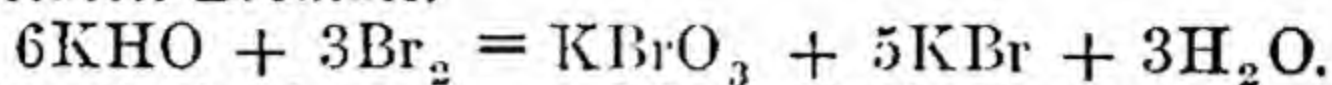


2—*Hypobromic Acid.*

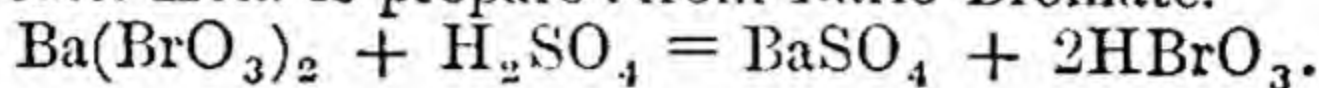




3—*Potassic Bromate.*



4—*Bromic Acid* is prepared from Baric Bromate.

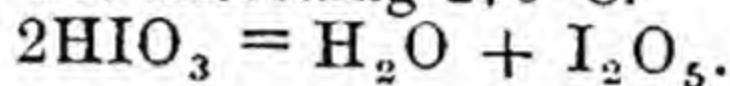


## Oxygen Compounds of Iodine.

$\text{I}_2\text{O}_5$  Iodic Anhydride     $\text{HIO}_3$  Iodic Acid.

$\text{I}_2\text{O}_7$  Periodic Anhydride     $\text{HIO}_4$  Periodic Acid.

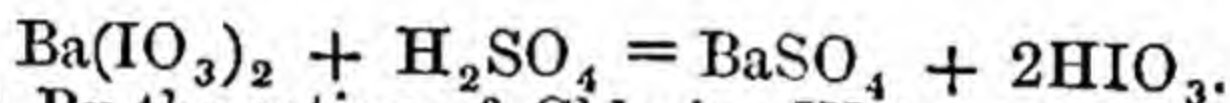
1—*Iodic Anhydride* is prepared by heating Iodic Acid to a temperature not exceeding  $170^\circ\text{C}$ .



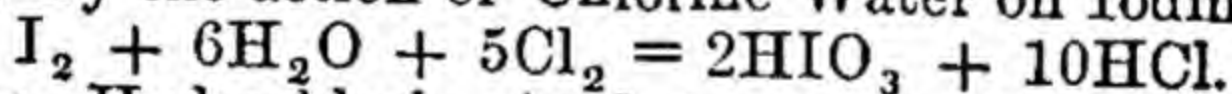
## Iodic Acid, $\text{HIO}_3$ .

1—*Preparation.*

(1) By the action of Sulphuric Acid on Barium Iodate.

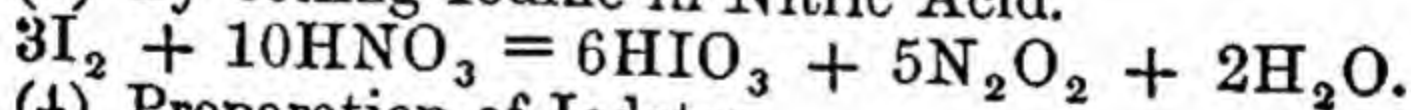


(2) By the action of Chlorine Water on Iodine.

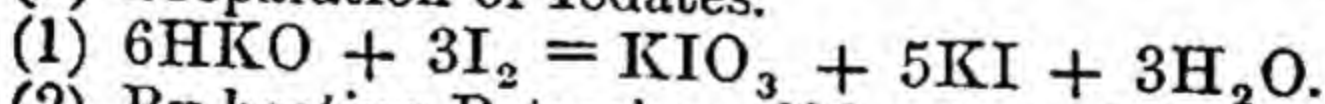


The Hydrochloric Acid is precipitated by adding finely divided Silver Oxide.

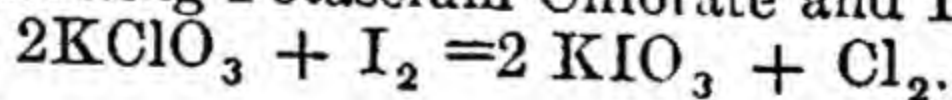
(3) By boiling Iodine in Nitric Acid.



(4) Preparation of Iodates.

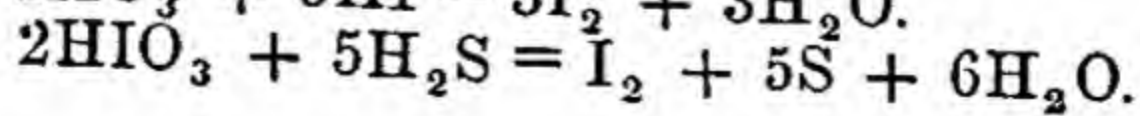
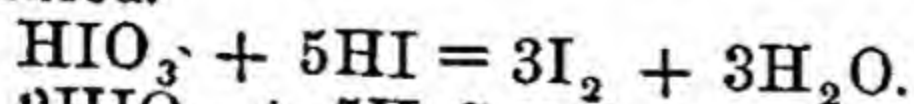


(2) By heating Potassium Chlorate and Iodine.



2—*Properties.*

A crystalline solid, insoluble in alcohol. It is very easily reduced.



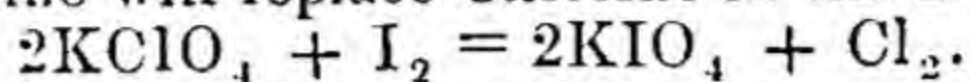




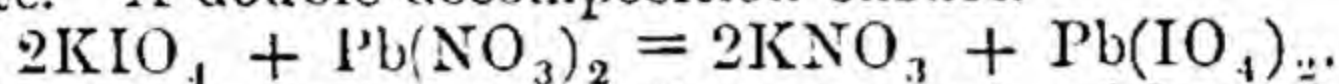
## Periodic Acid, $\text{HIO}_4$ .

### 1—*Preparation.*

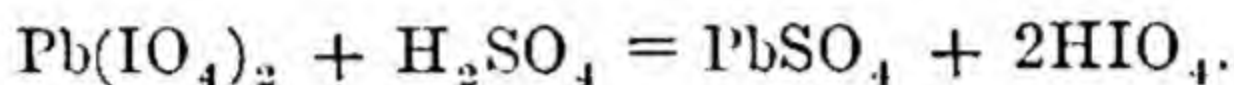
(1) Iodine will replace Chlorine in the Perchlorate.



(2) This Potassium Periodate is treated with Lead Nitrate. A double decomposition ensues.



(3) Lead Periodate is then treated with Sulphuric Acid.



### 2—*Properties.*

A colourless crystalline solid of no importance. The Acid is known only in Hydrated forms. The Anhydride can be prepared by heating the acid crystals to  $170^\circ\text{C}$ .

## Tabular View of Halogen Compounds.

Cl	Br	I	F
HCl	HBr	HI	HF
$\text{HClO} (\text{Cl}_2\text{O})$	$\text{HBrO} (\text{Br}_2\text{O})$	—	—
$\text{HClO}_2 (\text{Cl}_2\text{O}_3)$	—	—	—
$\text{Cl}_2\text{O}_4$			
$\text{HClO}_3$	$\text{HBrO}_3$	$\text{HIO}_3 (\text{I}_2\text{O}_5)$	
$\text{HClO}_4$	$\text{HBrO}_4$	$\text{HIO}_4 (\text{I}_2\text{O}_7)$	

## Sulphur.

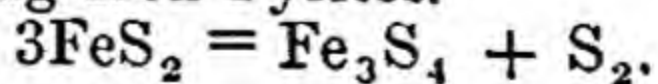
### 1—*Sources.*

Found native in volcanic districts. Found combined in Iron Pyrites,  $\text{FeS}_2$ , and Copper Pyrites  $(\text{FeCu})\text{S}_2$ .

### 2—*Preparation.*

(1) The Sulphur found native is purified by fusion and distillation.

(2) By heating Iron Pyrites.





3—*Physical Properties.*

(1) Yellow, solid, without taste or odour. Bad conductor of heat and electricity. Insoluble in water. Soluble in benzine, turpentine, oils, and Carbon Disulphide.

(2) Allotropic modifications.

Octohedral, when crystallised from solutions.

Prismatic " " from fusions.

Plastic, when heated to near its boiling point, and poured in a thin stream into cold water.

3—*Action of heat on Sulphur.*

(1) Fuses to a mobile liquid at  $115^{\circ}\text{C}$ .

(2) Becomes thick and viscid at  $220^{\circ}\text{C}$ .

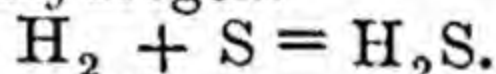
(3) Boils, first becoming very mobile, at  $440^{\circ}\text{C}$ .

(4) Vapour density at boiling point, 96.

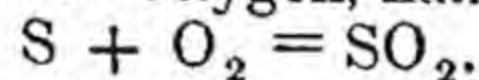
(5) Vapour density at  $900^{\circ}\text{C}$ , 32.

4—*Chemical Properties.*

(1) Combines directly with Hydrogen (*a*) when Hydrogen is passed through molten Sulphur, or (*b*) when Sulphur is burnt in Hydrogen.



(2) Burns in Air or Oxygen, flame being blue.

5—*Proof of Atomic weight.*

The Atomic weight is known from

(1) The vapour density of Sulphur.

(2) The proportion of Sulphur found in its volatile compounds.

## Compound of Sulphur with Hydrogen.

$\text{H}_2\text{S}$  = Hydrogen Sulphide, Sulphuretted Hydrogen.

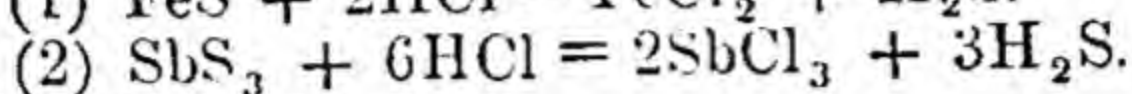
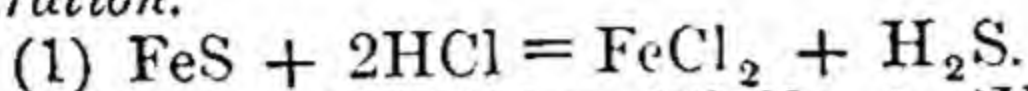
$\text{H}_2\text{S}_2$  = Hydrogen Persulphide.





## Hydrogen Sulphide, $\text{H}_2\text{S}$ .

### 1—*Preparation.*

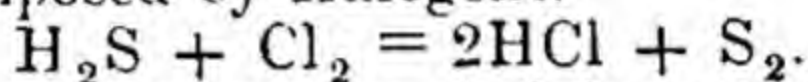


### 2—*Physical Properties.*

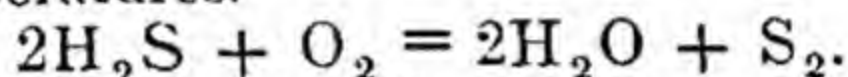
Colourless gas with fetid odour. At ordinary temperature Water dissolves about three times its own volume of Sulphuretted Hydrogen.

### 3—*Chemical Properties.*

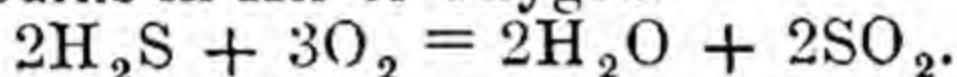
(1) Decomposed by Halogens.



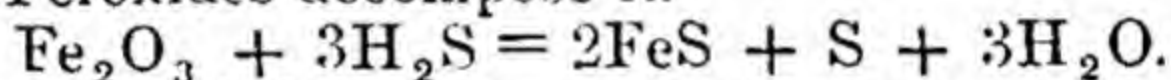
(2) Oxygen decomposes Sulphuretted Hydrogen at ordinary temperatures.



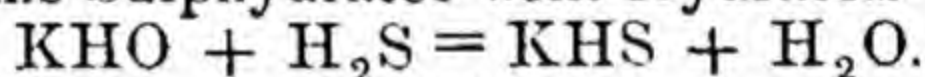
(3) It burns in Air or Oxygen.



(4) Peroxides decompose it.



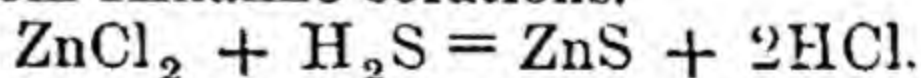
(5) Forms Sulphydrates with Hydrates.



(6) Precipitates the Sulphides of Silver, Mercury, Lead, Copper, Bismuth, Antimony, Arsenic, Tin, from Acid solutions.



(7) Precipitates Zinc, Manganese, Iron, Aluminium, Chromium from Alkaline solutions.



### 4—*Proof of Composition.*

(1) By burning a morsel of Tin or Potassium in the gas it is found that after combustion a volume of Hydrogen remains equal to the volume of gas taken. Therefore, Hydrogen Sulphide contains its own volume of Hydrogen.

Now, 22.4 litres of Hydrogen Sulphide weigh 34 grammes and 22.4 litres of Hydrogen weigh 2 grammes, therefore the weight of Sulphur present is 32 grammes,



which is the relative weight of the atom of Sulphur. Therefore, Hydrogen Sulphide contains 2 atoms of Hydrogen and 1 atom of Sulphur.

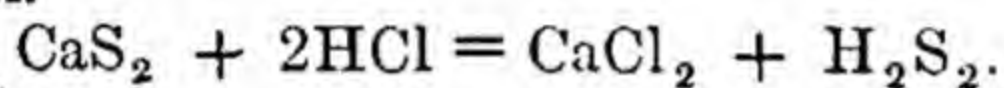
#### 5—*Tests for Sulphides.*

When treated with Acids they evolve a gas which blackens lead paper and has a characteristic odour.

## Hydrogen Persulphide, $\text{H}_2\text{S}_2$ .

#### 1—*Preparation.*

Flowers of Sulphur are boiled with Slaked Lime. The clear cold solution contains Calcium Disulphide  $\text{CaS}_2$ . It is poured gradually into dilute Hydrochloric Acid. Yellow drops of Hydrogen Persulphide settle at the bottom of the vessel.



#### 2—*Properties.*

Analogous to Hydrogen Peroxide.

## Compounds of Sulphur with Chlorine.

$\text{S}_2\text{Cl}_2$  = Sulphur Monochloride.

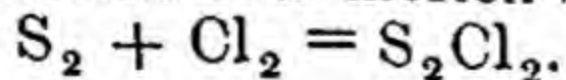
$\text{S Cl}_2$  = Sulphur Dichloride.

$\text{S Cl}_4$  = Sulphur Tetrachloride.

## Sulphur Monochloride, $\text{S}_2\text{Cl}_2$ .

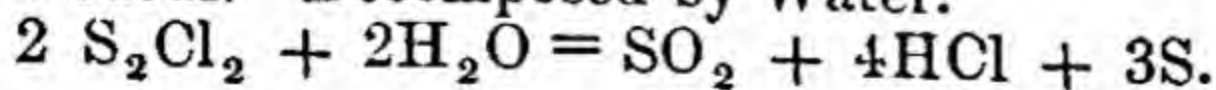
#### 1—*Preparation.*

By passing Chlorine over molten Sulphur.



#### 2—*Properties.*

A yellowish liquid which fumes in air and has an unpleasant odour. Decomposed by Water.





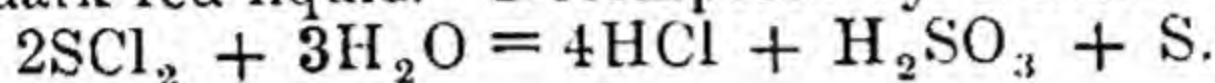
## Sulphur Dichloride, $\text{SCl}_2$ .

### 1—*Preparation.*

By passing a current of Chlorine into Sulphur Monochloride.

### 2—*Properties.*

A dark red liquid. Decomposed by Water.



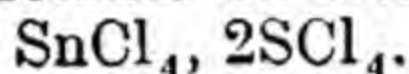
## Sulphur Tetrachloride, $\text{SCl}_4$ .

### 1—*Preparation.*

By saturating the Dichloride with Chlorine at  $-22^\circ\text{C}$ .

### 2—*Properties.*

Combines with Metallic Chlorides.



## Compounds of Sulphur with Oxygen.

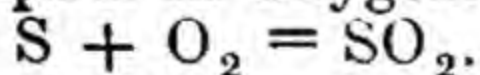
$\text{SO}_2$  Sulphurous Anhydride       $\text{H}_2\text{SO}_3$  Sulphurous  
Acid. Hydrogen Sulphite.

$\text{SO}_3$  Sulphuric Anhydride       $\text{H}_2\text{SO}_4$  Sulphuric  
Acid. Hydrogen Sulphate.

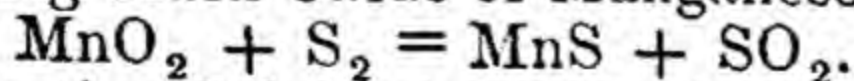
## Sulphurous Anhydride, $\text{SO}_2$ .

### 1—*Preparation.*

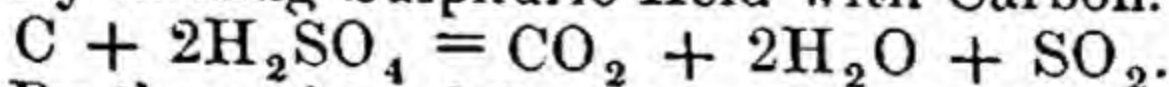
(1) Igniting Sulphur in Oxygen.



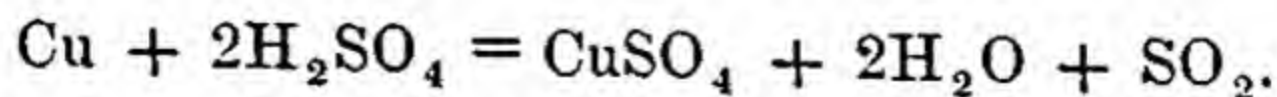
(2) Heating Black Oxide of Manganese with Sulphur.



(3) By heating Sulphuric Acid with Carbon.



(4) By the action of Copper or Mercury on Sulphuric Acid.





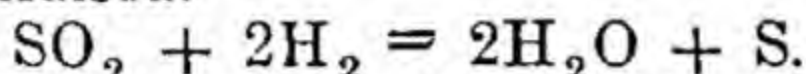


## 2—Physical Properties,

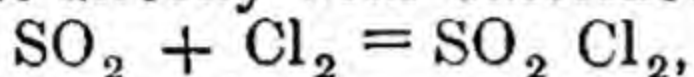
Colourless gas, with characteristic odour. Very soluble in Water. One volume of Water dissolves 100 vols. of the gas at 0°C.

## 3—Chemical Properties.

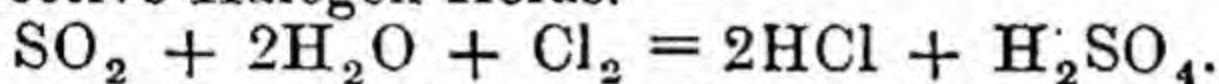
(1) Passed with Hydrogen through a hot porcelain tube it is de-oxidised.



(2) Combines directly with Chlorine.

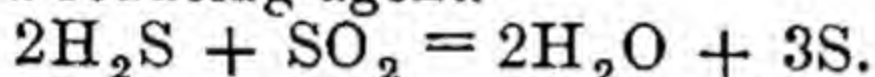


(3) With Halogens in the presence of Water it yields the respective Halogen Acids.

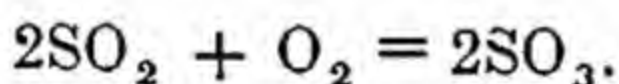


The theory of this is that Chlorine deoxidises the Water combining with Hydrogen, while the Oxygen liberated from the Water oxidises the Sulphurous Anhydride

(4) It is a reducing agent.



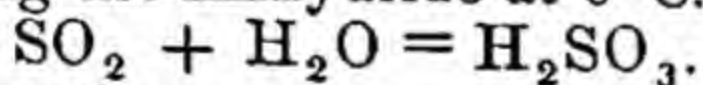
(5) When passed over spongy Platinum it combines with Oxygen.



## Hydrogen Sulphite. Sulphurous Acid, $\text{H}_2\text{SO}_3$ .

### 1—Preparation.

By Hydrating the Anhydride at 0°C.

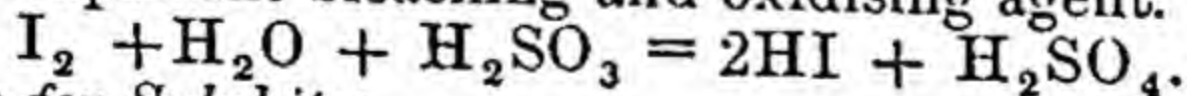


### 2—Physical Properties.

Colourless liquid with Sulphurous smell.

### 3—Chemical Properties.

An important bleaching and oxidising agent.



### 4—Tests for Sulphites.

(1) Sulphuric Acid, causing evolution of  $\text{SO}_2$ .

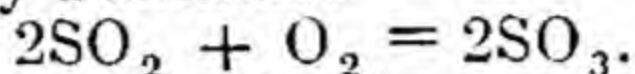
(2) Nascent Hydrogen ( $\text{Zn} + \text{H}_2\text{SO}_4$ ) causes an evolution of Hydrogen Sulphide which blackens lead paper.



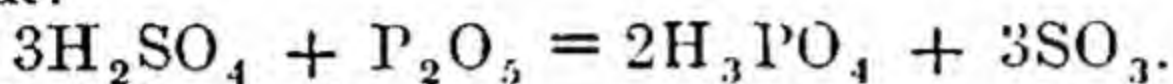
## Sulphuric Anhydride, $\text{SO}_3$ .

### 1—*Preparation.*

(1) By passing Sulphurous Anhydride and Oxygen over heated spongy Platinum.



(2) By dehydrating Sulphuric Acid by Phosphoric Anhydride.



### 2—*Physical Properties.*

At ordinary temperatures it is fibrous solid, similar to Asbestos. There is also a liquid variety which crystallises at  $16^\circ\text{C}$  in transparent prisms. The two varieties are *isomeric*.

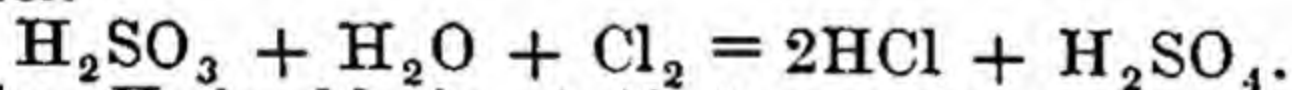
### 3—*Chemical Properties.*

Combines with Water with much violence, giving Sulphuric Acid.

## Hydrogen Sulphate. Sulphuric Acid, $\text{H}_2\text{SO}_4$ .

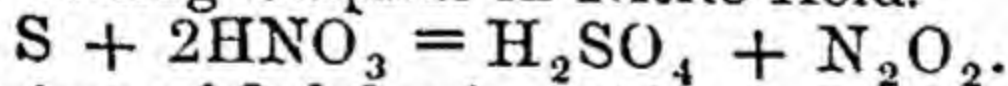
### 1—*Preparation.*

(1) By the action of Chlorine on Hydrogen Sulphite in Water.



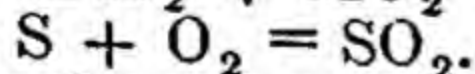
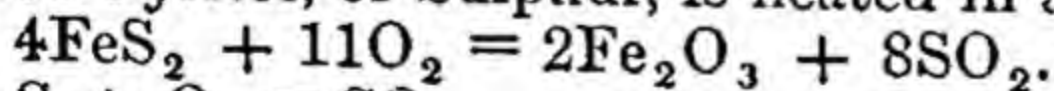
The Hydrochloric Acid is precipitated by Silver Nitrate.

(2) By boiling Sulphur in Nitric Acid.

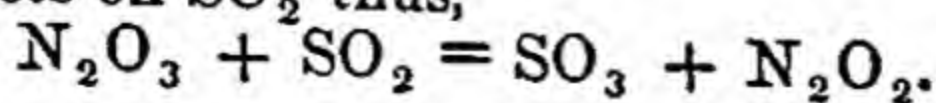


### 3—*Manufacture of Sulphuric Acid.*

(1) Iron Pyrites, or Sulphur, is heated in air.



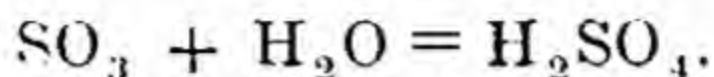
(2) In the same place Nitrates are heated, yielding  $\text{N}_2\text{O}_2$ , which at once combines with the Oxygen of the air, forming  $\text{N}_2\text{O}_3$ . In the presence of Water, this Nitrous Anhydride acts on  $\text{SO}_2$  thus,







(3) The Sulphuric Anhydride is hydrated by jets of steam.



(4) The Sulphuric Acid is concentrated by evaporation in porcelain or platinum basins.

## 2—Physical Properties.

A heavy, oily, colourless liquid. Specific gravity, 1.84. Boiling point,  $338^\circ\text{C}$ . A great dessicator.

## 3—Chemical Properties.

(1) Combines with Water evolving much heat, and forming definite hydrated compounds.

(2) Forms two distinct Salts with Monad bases, *e.g.*,

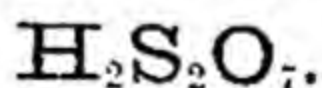


## 3—Tests for Sulphates.

(1) White precipitate with Barium Chloride insoluble in Hydrochloric Acid.

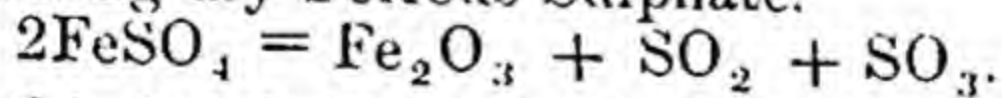
(2) The following are the insoluble Sulphates:—  
 $\text{BaSO}_4$ ,  $\text{SrSO}_4$ ,  $\text{PbSO}_4$ .

# Nordhausen Sulphuric Acid,



## 1—Preparation.

By distilling dry Ferrous Sulphate.



When this Sulphuric Anhydride is dissolved in very little Water, or in ordinary Sulphuric Acid, it forms a compound having the composition  $\text{H}_2\text{SO}_4, \text{SO}_3$ .

## 2—Properties.

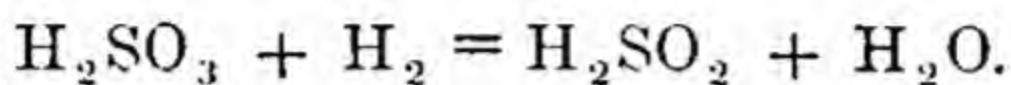
A brown, fuming liquid, decomposed by heat, yielding ordinary Sulphuric Acid. Used as a solvent for Indigo.



## Hyposulphurous Acid, $\text{H}_2\text{SO}_2$ .

### 1—*Preparation.*

By the action of Nascent Hydrogen on Sulphurous Acid.



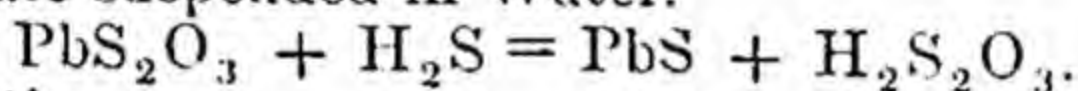
### 2—*Properties.*

Absorbs Oxygen from Air. Reduces Argentic Nitrate. Decolourises Indigo.

## Thiosulphuric Acid, $\text{H}_2\text{S}_2\text{O}_3$ .

### 1—*Preparation of the Acid.*

By passing Sulphuretted Hydrogen through Lead Thiosulphate suspended in Water.

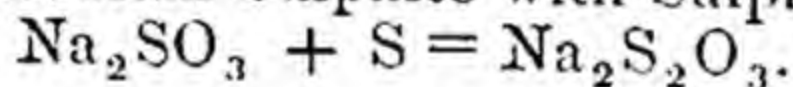


### 2—*Properties.*

A very irritant Acid, which has some important Salts.

#### *Preparation of the Thiosulphates.*

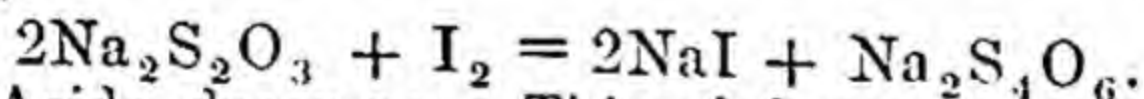
By boiling Sodium Sulphite with Sulphur.



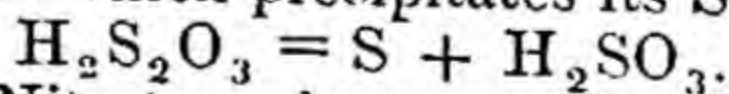
#### *Properties.*

(1) The Thiosulphates of the Alkalis, and of Magnesium, and Zinc are soluble.

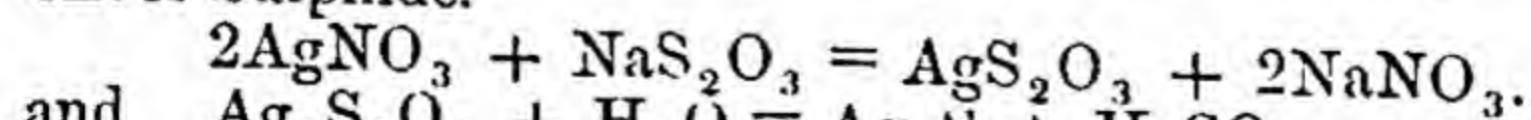
(2) They decolourise tincture of Iodine, forming Tetrathionates.



(3) Acids decompose Thiosulphates by first forming the unstable Acid which precipitates its Sulphur.

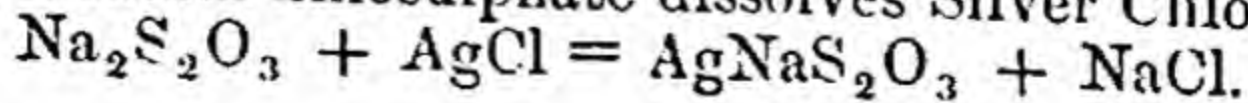


(4) Silver Nitrate gives a black precipitate of Silver Sulphide.



and  $\text{Ag}_2\text{S}_2\text{O}_3 + \text{H}_2\text{O} = \text{Ag}_2\text{S} + \text{H}_2\text{SO}_4.$

(5) Sodium Thiosulphate dissolves Silver Chloride.





The soluble compound  $\text{AgNaS}_2\text{O}_3$ , where each atom of basic Hydrogen is replaced by a different metal, is called a *double salt*.

### Table of the Chief Acids of Sulphur.

$\text{H}_2\text{S}$	=	Hydrogen Sulphide	=	Sulphuretted Hydrogen.
$\text{H}_2\text{SO}_2$	=	Hydrogen Hyposulphite	=	Hyposulphurous Acid.
$\text{H}_2\text{SO}_3$	=	Hydrogen Sulphite	=	Sulphurous Acid.
$\text{H}_2\text{SO}_4$	=	Hydrogen Sulphate	=	Sulphuric Acid.
$\text{H}_2\text{S}_2\text{O}_3$	=	Hydrogen Thiosulphate	=	Thiosulphuric Acid.

### The Nitrogen Group.

Non-metals.		Metalloids.		Metal.
Nitrogen & Phosphorus.		Arsenic & Antimony.		Bismuth.
N.	P.	As.	Sb.	Bi.
$\text{NH}_3$	$\text{PH}_3$	$\text{AsH}_3$	$\text{SbH}_3$	—
$\text{NCl}_3$	$\text{PCl}_3$	$\text{AsCl}_3$	$\text{SbCl}_3$	$\text{BiCl}_3$
$\text{N}_2\text{O}_3$	$\text{P}_2\text{O}_3$	$\text{As}_2\text{O}_3$	$\text{Sb}_2\text{O}_3$	$\text{Bi}_2\text{O}_3$
$\text{N}_2\text{O}_5$	$\text{P}_2\text{O}_5$	$\text{As}_2\text{O}_5$	$\text{Sb}_2\text{O}_5$	$\text{Bi}_2\text{O}_5$

### Nitrogen, N<sup>'''</sup> 14.

#### 1—Sources.

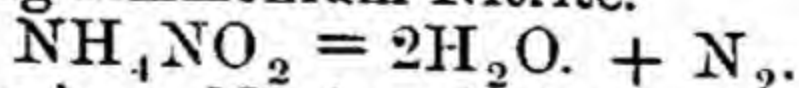
Air. Nitrites. Ammonia.

#### 2—Preparation.

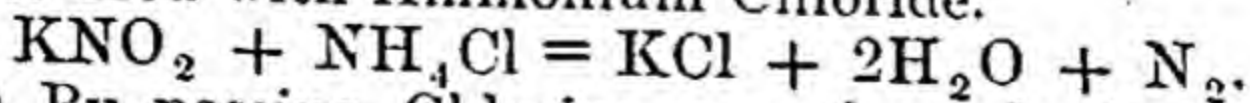
(1) By oxidising Phosphorus in Air.  $\text{P}_2\text{O}_5$  is soluble in Water, while Nitrogen remains undissolved.

(2) A solution of Pyrogallate of Potash will absorb Oxygen from Air, leaving Nitrogen.

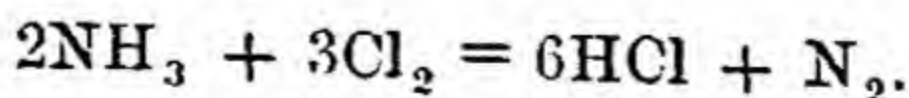
(3) Heating Ammonium Nitrite.



(4) Ammonium Nitrite being unstable, Potassium Nitrite is used with Ammonium Chloride.



(5) By passing Chlorine gas through Ammonia in excess.







If Chlorine be in excess a Chloride of Nitrogen is formed.

3—*Physical Properties.*

Colourless, tasteless, odourless, very slightly soluble in Water.

4—*Chemical Properties.* Entirely negative.

(1) Combines directly with Boron and Magnesium at red heat.

(2) Does not burn.

(3) Does not support combustion.

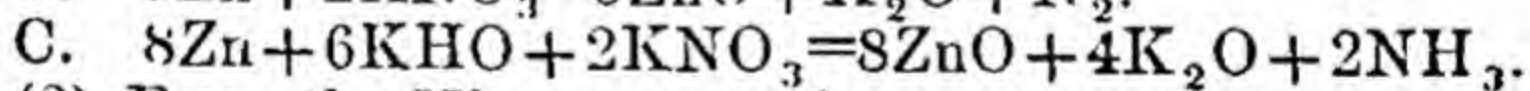
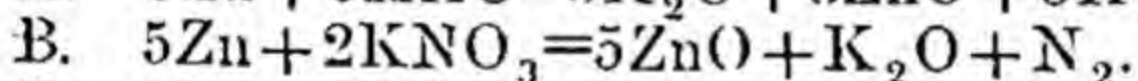
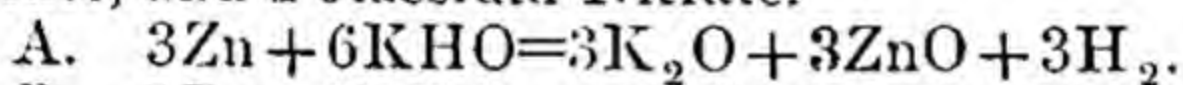
## Ammonia, $\text{NH}_3 = 17$ .

1—*Source.*

Ammonium Chloride, Manufacture of Coal Gas. The distillation of organic matter with Soda Lime.

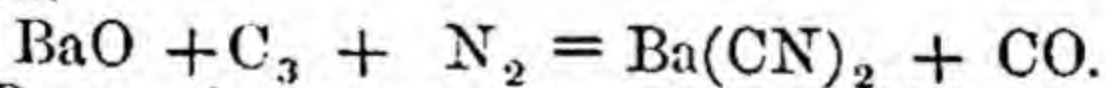
2—*Preparation.*

(1) By the direct union of Hydrogen and Nitrogen in the nascent state, *e.g.*, Heat a mixture of Zinc, Potassium Hydrate, and Potassium Nitrate.

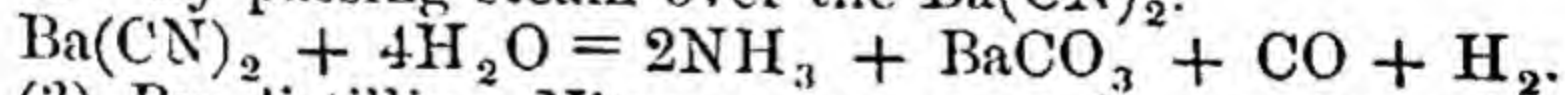


(2) From the Nitrogen of Air.

A. Pass Nitrogen over a mixture of Barium Oxide and Carbon.

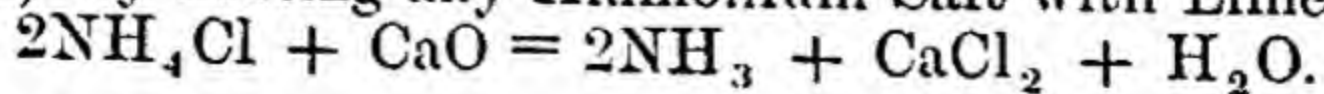


B. By passing steam over the  $\text{Ba}(\text{CN})_2$ .



(3) By distilling Nitrogenous organic matter with Alkalis, *e.g.*, Soda Lime. The Nitrogen of the organic compound distils over in union with Hydrogen as Ammonia

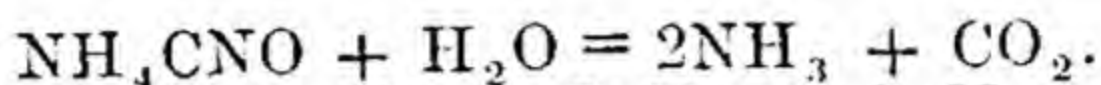
(4) By heating any Ammonium Salt with Lime.



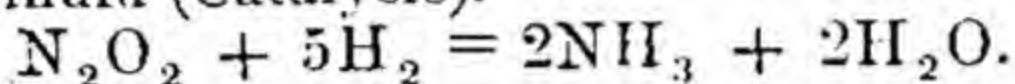


This is the usual method for preparing Ammonia in the Laboratory. Most of the Ammonia of commerce is a product of the destructive distillation of Coal. The following methods are of theoretical importance:—

(5) Ammonia is produced by the decomposition of Urea.



(6) By passing Nitric Oxide and Hydrogen over spongy platinum (Catalysis).

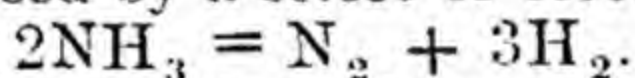


### 3—Physical Properties.

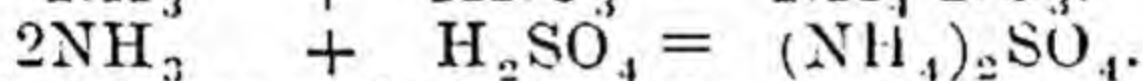
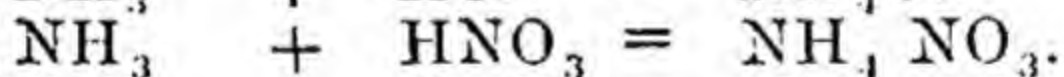
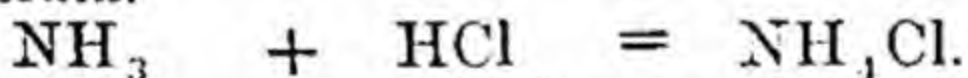
Colourless gas—Alkaline, with characteristic odour. Water at  $15^\circ$  dissolves 750 times its volume of Ammonia gas. Liquor Ammoniae is a solution of the gas in water. The gas is collected over Mercury, and dried by passing it over quick-lime. Calcium Chloride absorbs Ammonia.

### 4—Chemical Properties.

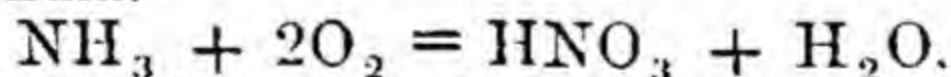
(1) Decomposed by a series of electric sparks.



(2) Unites with Acids without displacing the Hydrogen, forming Salts isomorphous with the Salts of Sodium and Potassium.

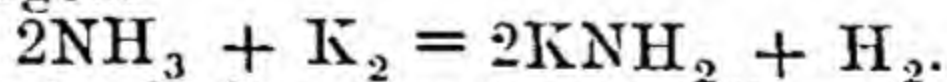


(3) Combines with Oxygen in the presence of heated spongy Platinum.



Mixed with Oxygen it burns with a greenish yellow flame.

(4) Potassium, when heated in Ammonia Gas, replaces Hydrogen.



(5) Certain bodies, such as Silver Chloride and Calcium Chloride, absorb many times their own volume of Ammonia Gas, and yield it again on heating.

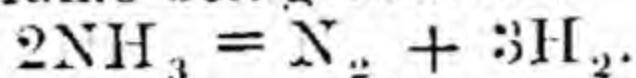




(6) It is decomposed on passing it through a hot porcelain tube.

6—*Proof of Composition.*

(1) *By analysis.* By passing a series of electric sparks through Ammonia in an eudiometer, the gas is decomposed, its volume being doubled.



The amount of Hydrogen liberated from the Ammonia can be estimated by doubling the volume of Oxygen required to burn it. The residual gas is Nitrogen.

(2) *By Chlorine.* Ammonia is added to a graduated tube containing Chlorine till all the Chlorine has disappeared. Hydrochloric Acid and Nitrogen are thus formed. If now a dilute solution of Hydrochloric Acid be admitted to the tube, all the Hydrochloric Acid formed will dissolve. If Mercury now be admitted to the vacuum thus formed, it will be found that the Nitrogen occupies one third of the volume of Chlorine originally present. But Chlorine and Hydrogen combine in equal volumes, therefore the volume of Nitrogen in Ammonia is one third of the Hydrogen. Hence, if the volume of Nitrogen be one, the volume of Hydrogen must be three. The formula for Ammonia is thus  $\text{NH}_3$ .

6—*Tests for Ammonia.*

- (1) Odour.
- (2) Turns red litmus blue.
- (3) Gives white fumes of  $\text{NH}_4\text{Cl}$  with Hydrochloric Acid.
- (4) Yellow precipitate with Nessler's Solution.
- (5) Gives a deep blue colour with Copper Salts.

### Ammonium, $\text{NH}_4$ .

1—From the behaviour of Ammonia with Acids, it is conjectured that there is a basic radicle Ammonium ( $\text{NH}_4$ ). This radicle, however, has never been isolated. The evidence for its existence is :—



(1) Ammonia forms with acids, salts that are isomorphous with Sodium and Potassium Salts.

(2) The solution of Ammonia in Water behaves as the Alkaline Hydrates  $\text{KHO}$  and  $\text{NaHO}$ .

Thus  $\text{NH}_3, \text{H}_2\text{O} = (\text{NH}_4)\text{HO}$ , which may be compared to  $\text{KHO}$ .

The production of the so-called Ammonium Amalgam is not evidence. This curious body can be prepared by electrolysing a solution of Ammonic Chloride, Mercury being employed as the electrode where the current leaves the solution. It may also be prepared by making first the Sodium Amalgam, and then treating it with a solution of Ammonic Chloride. A spongy mass, of metallic appearance, begins to float in the solution. Examination proves that it is not a genuine amalgam. It is merely Mercury inflated with Ammonia and Hydrogen.

## Halogen Compounds of Nitrogen.

The Chloride, Bromide, and Iodide of Nitrogen are known— $\text{NCl}_3$ ,  $\text{NBr}_3$ ,  $\text{NI}_3$ . They are dangerous explosive compounds. Iodide of Nitrogen may be prepared by digesting a little Iodine in a cold solution of Ammonia. A black insoluble powder is obtained. This is  $\text{NI}_3$ , or a mixture of  $\text{NI}_3$  and  $\text{NHI}_2$ . If a little of this powder is placed on blotting paper and allowed to dry, it will detonate loudly on the slightest motion.

## Oxygen Compounds of Nitrogen.

Oxides and Anhydrides.	Acids.
$\text{N}_2\text{O}$ Nitrous Oxide.	( $\text{HNO}$ Hyponitrous Acid).
$\text{N}_2\text{O}_2$ Nitric Oxide.	
$\text{N}_2\text{O}_3$ Nitrous Anhydride.	$\text{HNO}_2$ Nitrous Acid.
$\text{N}_2\text{O}_4$ Nitric Peroxide.	
$\text{N}_2\text{O}_5$ Nitric Anhydride.	$\text{HNO}_3$ Nitric Acid.

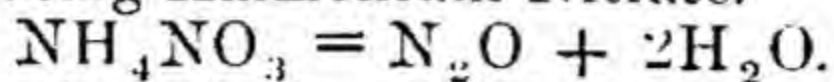




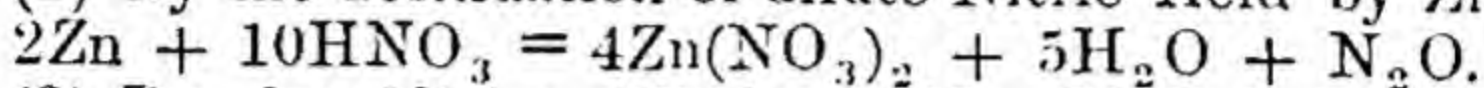
## Nitrous Oxide, $N_2O$ .

### 1—*Preparation.*

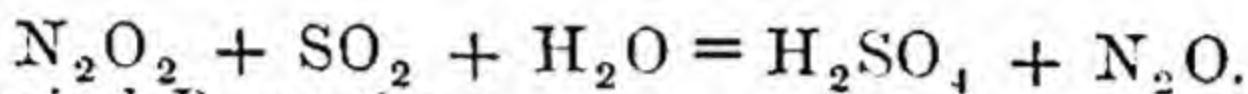
(1) By heating Ammonium Nitrate.



(2) By the deoxidation of dilute Nitric Acid by Zinc.



(3) By deoxidising Nitric Oxide ( $N_2O_2$ ) by such deoxidising agents as Sulphurous Anhydride and Iron filings.



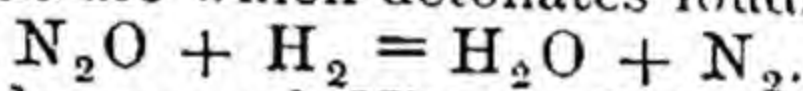
### 2—*Physical Properties.*

A colourless, odourless gas, with *sweet* taste. Soluble in water. Used as an anæsthetic. Laughing gas.

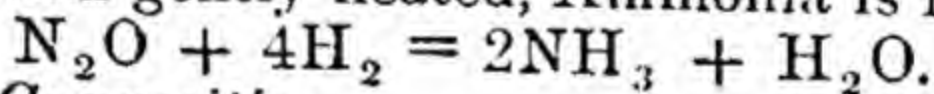
### 3—*Chemical Properties.*

(1) Does not burn but supports combustion. Bodies that combine with Oxygen burn at the expense of the Oxygen of Nitrous Oxide, the Nitrogen being left.

(2) Mixed with its own volume of Hydrogen, it forms an explosive mixture which detonates loudly.



(3) If Hydrogen and Nitrous Oxide be passed over spongy platinum gently heated, Ammonia is formed.



### 4—*Proof of Composition.*

On burning a small piece of Potassium in a bent tube filled with the gas, one end of the tube being open under Mercury and the other end closed, the Potassium combines with the Oxygen. But there is no change of volume. Therefore Nitrous Oxide contains its own volume of Nitrogen.

22.4 litres of Nitrous Oxide weigh	44 grms.
and 22.4        „        Nitrogen	28        „

	therefore there must be	—	
present.	We know that this weight of Oxygen occupies	16	„ of Oxygen





11.2 litres. The gas therefore contains 2 volumes of Nitrogen united to one volume of Oxygen, the whole forming 2 volumes of Nitrous Oxide.

(2) We might, using the result of the above experiment, proceed from the density of Nitrous Oxide.

Its density compared with Air is	...	1.527
Deduct the density of Nitrogen—that is the weight of an equal volume of Nitrogen	... ..	.972

This leaves	... ..	.555
-------------	--------	------

which is just half the density of Oxygen, or that is to say it represents the weight of half a volume of Oxygen.

Therefore 1.527 grammes of this gas contains .972 grammes of Nitrogen, and .555 grammes of Oxygen. From these figures we can deduce its percentage composition and its formula.

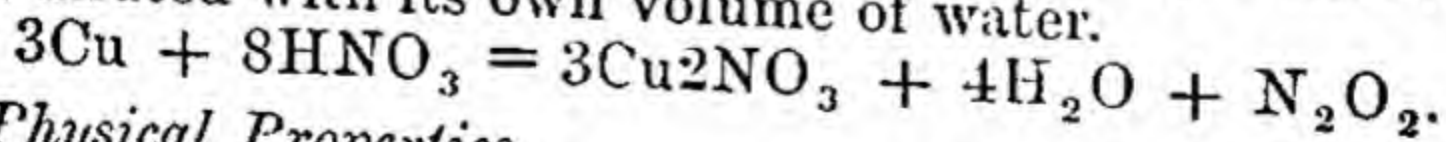
#### 5—*Tests for Nitrous Oxide.*

- (1) Does not burn in air.
- (2) Bodies that combine with Oxygen burn in it with great brilliance,
- (3) Does not turn Pyrogallate of Potash brown.
- (4) Does not give red fumes with Nitric Oxide.

### Nitric Oxide, $N_2O_2 = 2NO$ .

#### 1—*Preparation.*

- (1) By treating Copper, Lead, or Mercury with Nitric Acid diluted with its own volume of water.



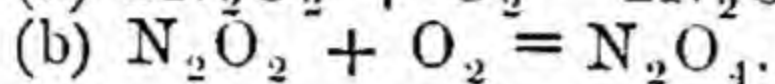
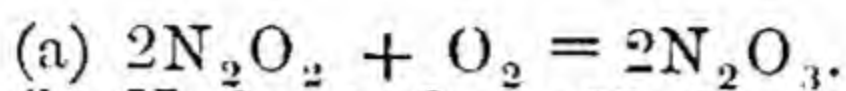
#### 2—*Physical Properties.*

A colourless gas which can be readily collected over water.



### 3—*Chemical Properties.*

(1) Combines readily with Oxygen, giving ruddy fumes.



(2) The gas is easily decomposed by bodies burning brilliantly when introduced into it. The Oxygen thus liberated causes the combustion to continue.

(3) The gas is absorbed by Ferrous solutions which turn brown. This will be turned to account to detect Nitric Acid.

### 4—*Proof of Composition.*

An experiment of the same character as that made in the case of Nitrous Oxide, will shew that any volume of this gas contains half its volume of Nitrogen. From this result we can deduce the volumetric composition, percentage composition and formula, as already shown for Nitrous Oxide.

### 5—*Tests for Nitric Oxide.*

(1) A colourless gas giving ruddy fumes on exposure to air or to Oxygen.

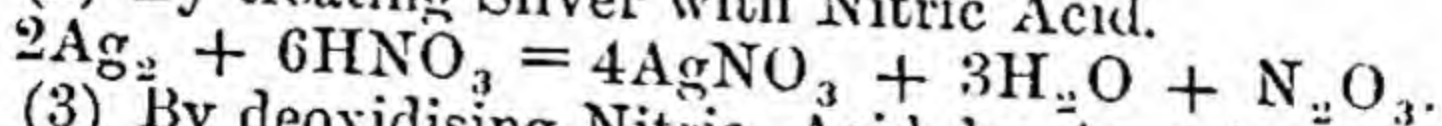
(2) These ruddy fumes dissolve in Ferrous Sulphate yielding a brown solution.

## Nitrous Anhydride, $\text{N}_2\text{O}_3$ .

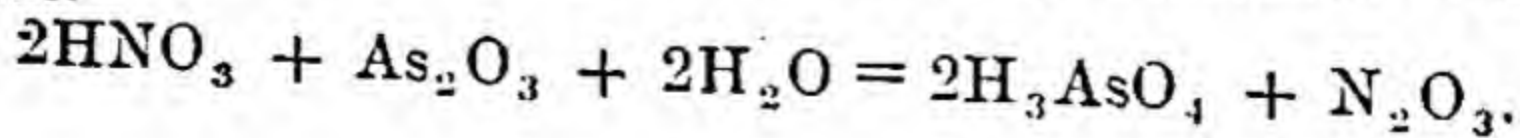
### 1—*Preparation.*

(1) By passing Oxygen and Nitric Oxide through a hot tube.

(2) By treating Silver with Nitric Acid.



(3) By deoxidising Nitric Acid by Arsenious Anhydride.

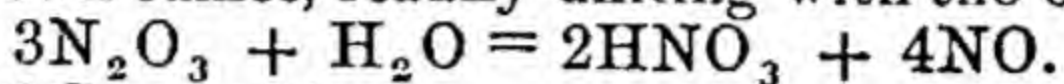






**2—Properties.**

The gas should be collected in a receiver surrounded by a freezing mixture. It forms a blue unstable liquid, yielding brown fumes, readily uniting with the cold Water.

**3—Proof of Composition.**

We know the composition of this gas from the fact that it is prepared by adding one volume of Oxygen to four volumes of Nitric Oxide.

## Nitrous Acid, $\text{HNO}_2$ .

**1—Preparation.**

By adding Water to the Anhydride.

**2—Tests for Nitrites.**

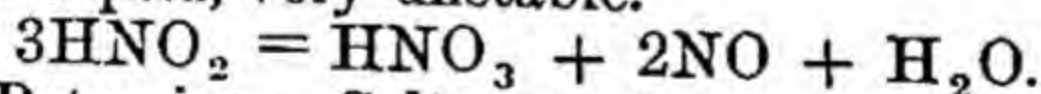
(1) When dilute Sulphuric Acid is added ruddy fumes are evolved.

(2) If starch paper, moistened with Potassic Iodide, is exhibited to their fumes, the starch paper turns blue owing to the liberation of Iodine.

(3) A solution of Potassium Permanganate is de-colourised.

**Properties.**

A blue liquid, very unstable.



The Potassium Salt can be prepared by heating Potassium Nitrate.

## Hyponitrous Acid, $\text{HNO}$ .

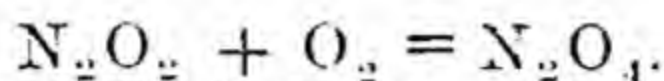
By deoxidising a solution of Potassium Nitrate by Sodium Amalgam, a salt having the composition indicated by the formula  $\text{KNO}$  has been prepared. Attempts to isolate the corresponding acid have failed. But an insoluble Silver Salt,  $\text{AgNO}$ , has been prepared.



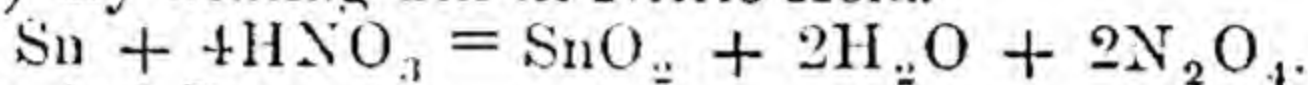
## Nitric Peroxide, $\text{N}_2\text{O}_4 = 2\text{NO}_2$ .

### 1—*Preparation.*

(1) By adding Nitric Oxide to half its volume of Oxygen.



(2) By heating Tin in Nitric Acid.

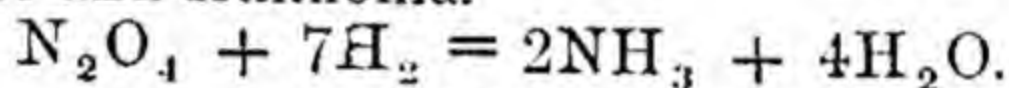


### 2—*Physical Properties.*

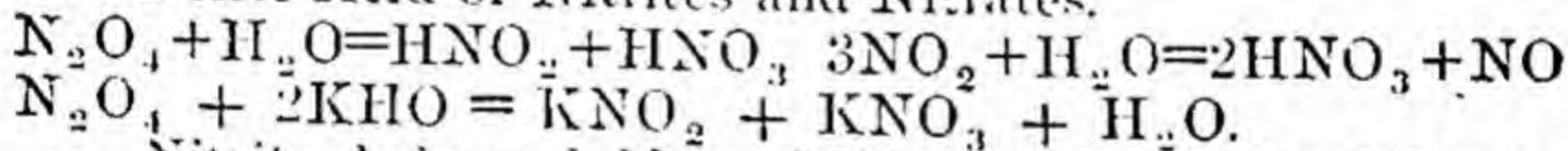
A red fuming vapour, easily condensed to liquid state. The liquid dissolves its own vapour, yielding a colour varying from light yellow to deep brown, according to the proportion of vapour dissolved.

### 3—*Chemical Properties.*

(1) Passed with Hydrogen over Spongy Platinum it yields Water and Ammonia.

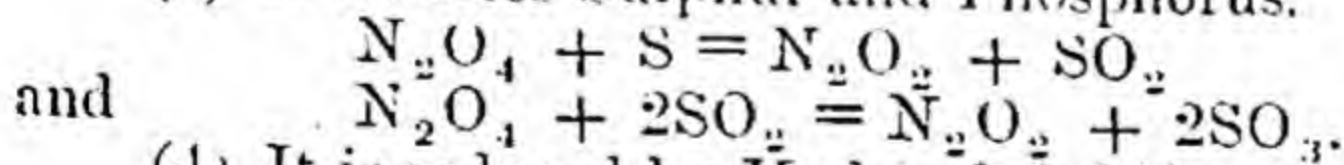


(2) It combines with Water and Hydrates, forming at low temperature Nitrous Acid, and at ordinary temperature Nitric Acid or Nitrites and Nitrates.

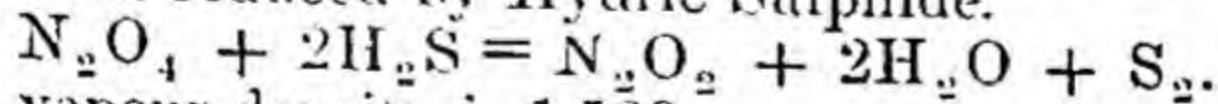


Nitrites being soluble and Nitrates being insoluble in Alcohol the salts can easily be separated.

(3) It oxidises Sulphur and Phosphorus.



(4) It is reduced by Hydric Sulphide.



Its vapour density is 1.589.

The vapour densities of Nitric Oxide and Nitric Peroxide are anomalous.

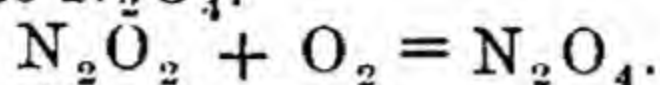
The vapour density of  $\text{N}_2\text{O}_4$  is 1.589. Therefore its molecular weight is

$$1.589 \times 14.4 \times 2 = 46.$$





But the preparation of this gas from Nitric Oxide by adding half its volume of Oxygen would lead us to impart that the formula is  $N_2O_4$ .



This would indicate a molecular weight of 92. But this is incompatible with its vapour density, which shows that the true formula is  $NO_2$ .

The same is true of Nitric Oxide.

Its vapour density is 1.04.

Its molecular weight should, therefore, be—

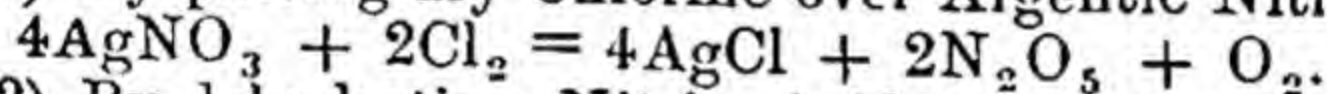
$$1.04 \times 14.4 \times 2 = \text{nearly } 30,$$

which is just half the weight according to the formula  $N_2O_2$ . Its vapour density indicates that  $NO$  is the formula for this gas. The adoption of these formulæ  $NO_2$  and  $NO$  destroys the apparent numerical sequence of the Nitrogen series, and obscures the relation of these two Oxides to other members of the series.

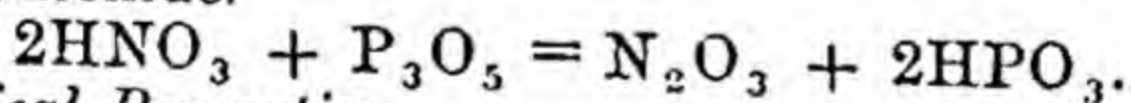
## Nitric Anhydride, $N_2O_5$ .

### 1—*Preparation.*

(1) By passing dry Chlorine over Argentic Nitrate.



(2) By dehydrating Nitric Acid by means of Phosphoric Pentoxide.

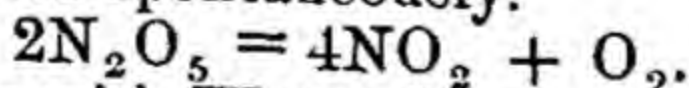


### 2—*Physical Properties.*

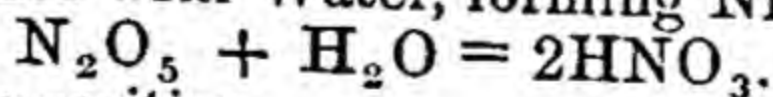
Colourless, crystalline, solid, very volatile, and soluble in Water.

### 3—*Chemical Properties.*

(1) Decomposes spontaneously.



(2) Combines with Water, forming Nitric Acid.



### 4—*Proof of Composition.*

By passing the vapour of  $N_2O_5$  over highly heated Copper the Anhydride is deoxidised,  $CuO$  being formed,





free Nitrogen passing on. This is collected and weighed. The increase of weight of the Copper gives the amount of the Oxygen. The sum of these two weights gives the weight of Nitric Anhydride decomposed. From these results we can calculate its percentage composition and formula.

## Nitric Acid, $\text{HNO}_3$ .

### 1—*Sources.*

Potassic and Sodid Nitrates. These Nitrates occur as efflorescences on soil containing Alkaline bases. Nitric Acid is formed in the atmosphere (1) by electrical discharges, (2) by the action of Ozone on moist Nitrogen, and (3) by the oxidation in air of Nitrogenous organic matter. This Nitric Acid combines with bases forming Nitrates.

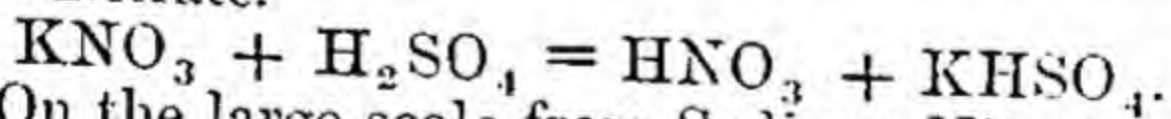
### 2—*Nitrification.*

(1) If a heated Platinum spiral wire be raised to white heat, and be plunged in a mixture of Air and Ammonia Gas, the spark will continue to glow, and the mixed gases that were forming Alkaline will now yield an acid reaction with litmus. Nitric Acid has been produced.

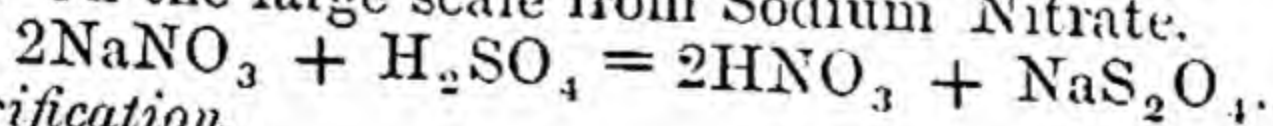
(2) If a heap of Nitrogenous organic matter be mixed with Lime and allowed to rot, the oxidised Nitrogen will combine with the Lime forming Calcium Nitrate.

### 3—*Preparation.*

(1) In the laboratory by distilling Sulphuric Acid and Potassium Nitrate.



(2) On the large scale from Sodium Nitrate.



### 4—*Purification.*

Nitric Acid contains vapours of lower Oxides of Nitrogen. It may also contain Sulphuric Acid that has been carried over in distillation, and Hydrochloric Acid from Sodium Chloride salt in the Nitre.



Boiling will remove the lower Oxides.

Lead Nitrate will precipitate the Sulphuric Acid as Plumbic Sulphate which will remain in the retort if the Acid is distilled.

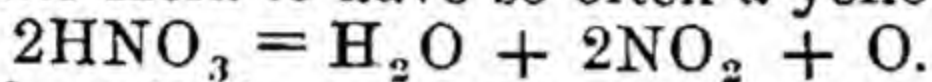
Silver Nitrate will precipitate any Chloride.

### 5—Physical Properties.

A colourless fuming liquid, with characteristic odour.

### 3—Chemical Properties.

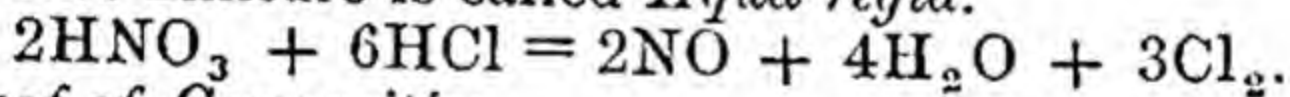
(1) Light decomposes it. Lower Oxides are formed which cause the Acid to have so often a yellow colour.



(2) Sulphur, Iodine, and Phosphorus, when boiled in Nitric Acid yield Sulphuric, Iodic and Phosphoric Acids respectively.

(3) Its oxidising power can be demonstrated by pouring a little of the strong Acid on gently warmed, finely divided Carbon. The Carbon is at once oxidised to Carbonic Acid. Turpentine can be oxidised by the addition of Nitric Acid, dehydrated by a little strong Sulphuric Acid.

(4) With Hydrochloric Acid it yields Nascent Chlorine. This mixture is called *Aqua regia*.



### 6—Proof of Composition.

Nitric Acid is neutralised by an observed weight of Lead. The weight of dry Lead Nitrate produced is noted. The Lead Nitrate is then decomposed, and the evolved gases ( $\text{N}_2\text{O}_4 + \text{O}$ ) are passed over highly heated Copper, which is thereby converted into CuO, the Nitrogen being set free. The weight of this Nitrogen is the weight of Nitrogen present in the Lead Nitrate. The amount of Lead present is known. The amount of Oxygen is obtained by subtracting the weight of Lead and of Nitrogen from the total weight. Thus we arrive at the weight of Lead, Nitrogen, and Oxygen in Lead Nitrate.

From these data we can calculate the percentage composition of Lead Nitrate, and calculate the formula  $\text{PbN}_2\text{O}_6$ .





Now, as we cannot, by any means, whatever, form a Salt having the composition  $\text{KHN}_2\text{O}_6$ , we are led to the conclusion that Nitric Acid is monobasic, and as we know that Lead is a dyad we must assign to the Acid the formula  $\text{HNO}_3$ , and to Lead Nitrate the formula  $\text{Pb}''2\text{NO}_3$ .

This formula agrees with the molecular weight of Nitric Acid deduced from its vapour density. Its density at  $88^\circ\text{C}$  is found to be 2.05.

$2.05 \times 14.4 \times 2 = \text{nearly } 60$ ,  
which is sufficiently near to 63 to justify the adoption of the formula  $\text{HNO}_3$  in preference to any other.

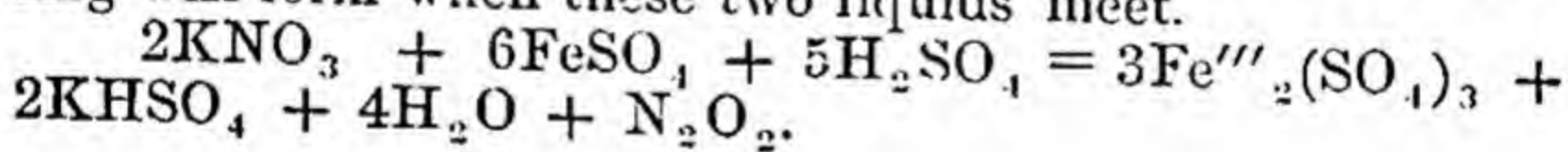
7—*Tests for Nitrates.*

(1) All soluble.

(2) In the presence of  $\text{H}_2\text{SO}_4$  they evolve red fumes when Copper is added.

(3) Deflagrate on Charcoal, and decrepitate when heated as most crystals do which contain no water of crystallisation.

(4) Dissolve a crystal of Ferrous Sulphate in the liquid to be tested, which has been allowed to cool after the addition of some strong Sulphuric Acid. A brown ring will form when these two liquids meet.



## The Atmosphere.

1—Air is not a chemical compound. It is a mechanical mixture of several gases, but chiefly of Nitrogen and Oxygen.

2—The following reasons induce us to believe that air is a mechanical mixture and not a chemical compound:

(1) The proportions of the constituents are not absolutely constant.



(2) The proportions are not those of the combining weights, and bear no simple relation to them.

(3) When the constituents are brought together there is no change of temperature or volume, and yet the mixture has all the properties of ordinary air.

(4) The constituents can be separated out by mere mechanical means, such as solution or diffusion.

(5) The radiant heat absorbed by atmospheric air accords with the comparatively small amount that would be absorbed by a mixture of simple gases, and not with the comparatively large amount that is absorbed by compound gases.

(6) The density of the atmosphere and its refractive power, are the respective means which would result from a mere mixture of simple constituents. In compounds the density and refractive power are not necessarily the means of the density and refractive power of the constituents.

### 3—*Constitution of Air.*

Although Priestley was the first to obtain Oxygen Gas, he did not rightly understand its connection with air, or its relation to combustion. This fertile discovery was left to Lavoisier. Priestley regarded Oxygen as a very pure air or gas which could, as it were, soak up in its interstices the material of a candle burning in it; air already contained some such material in its interstices and therefore could not support combustion so readily. Lavoisier shewed that ordinary Combustion was combination with Oxygen, and that Air was a less active supporter of combustion, not because it was partially saturated, but because it was diluted. This he proved by obtaining one measure of Oxygen from every five of Air, the remaining four measures having no power of supporting Combustion; and by proving that when substances burn in air, the new bodies formed weigh more than the original substance, so that matter has been taken from, not added to, the Air.





# Composition of the Atmosphere.

Constituent	Amount	Sources	Presence proved by
Oxygen ...	20.6 %	Present from the beginning. Exhaled by plants.	Warming Mercury in Air, and then heating the Oxide so prepared to a higher temperature.
Nitrogen ...	79.4 %	Present from the beginning.	By absorbing the Oxygen by Pyrogallate of Potash.
Carbon Dioxide ...	.04 %	Combustion, Putrefaction, Respiration, Fermentation.	Turns Lime-water milky.
Aqueous Vapour ..	.4 to 1.6 %	Evaporation.	By Hygroscopic bodies.
Ozone ...	Variable traces.	The action of Electricity on Oxygen.	Starch Paper moistened with Potassium Iodide.
Sulphuric Acid ...	Traces.	Combustion and decay of Organic matter.	By passing Air through distilled Water, these bodies may be held by the Water and recognised by distinctive tests.
Ammonia ...	"	"	"
Nitric Acid ...	"	"	"
Dust ...	"	Various.	A sunbeam in a dark room.
Organic Germs ...	"	"	Fermentation, &c.





#### 4—*Proof of Constitution.*

(1) By gently heating Mercury in Air till all the Oxygen had combined with the Mercury, Lavoisier found that the Nitrogen left was four-fifths of the volume of the air employed.

(2) After burning Phosphorus in a jar full of air, the Phosphorus Pentoxide formed dissolves in the water. The water rises one-fifth of the way up the jar. The remaining gas is Nitrogen.

(3) On shaking up a volume of Air with Pyrogallate of Potash the Oxygen is absorbed. If the tube containing the air be now opened under Mercury, the Mercury will rise one-fifth of the way up the tube. The residual body is Nitrogen.

(4) By measuring the amount of Hydrogen required to burn the Oxygen in air. Let  $V$  = any volume of air. And  $V'$  equal the amount of Hydrogen introduced.

$V''$  = volume remaining after explosion.

Then  $V + V' - V''$  is the volume of gas that has disappeared as gas during the conversion into water. One-third of this volume must be Oxygen,

Therefore the amount of Nitrogen in air is

$$V - \frac{V + V' - V''}{3}$$

This method is applicable directly to such gases as the Oxides of Nitrogen, and conversely to Ammonia Gas when decomposed by Electricity, Oxygen being added in the latter case.

(5) The composition of air by weight is ascertained by passing air over highly heated Copper. The Copper is oxidised. The increase of weight of the Copper measures the Oxygen. Nitrogen passes on into an exhausted globe of known weight. The increase of the weight of the globe measures the Nitrogen. Thus we know the amount of Oxygen and of Nitrogen in a weight of air equal to the weight of these constituents.



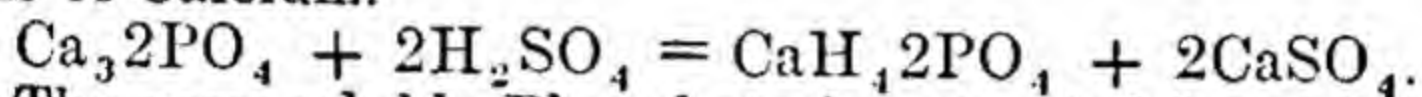
## Phosphorus, P''' 31.

1—*Sources.*

Phosphates of Calcium and Magnesium. Plants. Brain, Urine, and Bones of animals. Bone ash contains 80 per cent. of Calcium Phosphate,  $\text{Ca}_32\text{PO}_4$ .

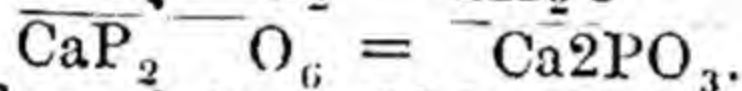
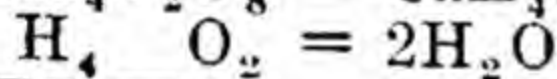
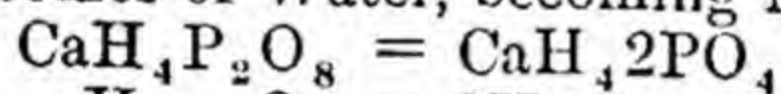
2—*Preparation from Bone Ash.*

(1) Calcium Phosphate (Bone Ash) is treated with Sulphuric Acid. The Hydrogen of the Acid replaces two atoms of Calcium.

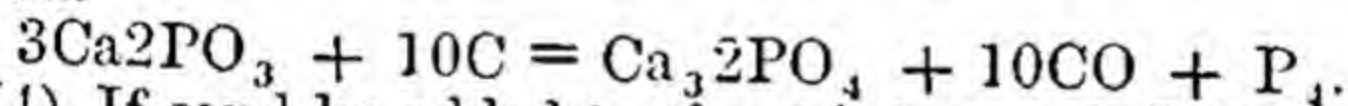


The very soluble Phosphate is extracted from the very slightly soluble Sulphate by Water and afterwards evaporated, and when of syrupy consistence is mixed with Carbon.

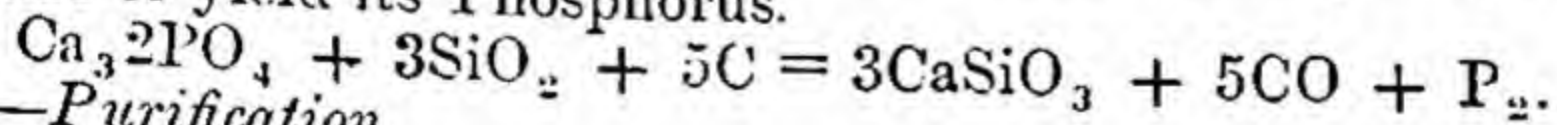
(2) At red heat the Calcium Tetrahydric Phosphate loses two molecules of Water, becoming Metaphosphate.



(3) The dry mixture of Metaphosphate and Carbon is distilled.



(4) If sand be added to the mixture of Calcic Metaphosphate and Carbon, the whole of the Phosphorus can be distilled off. Silicon displacing Phosphorus will form Calcium Silicate. The  $\text{Ca}_32\text{PO}_4$ , always produced when the mixture is heated without sand, is thus decomposed, and made to yield its Phosphorus.

3—*Purification.*

Phosphorus is purified by fusion in Water with bleaching powder and filtration through wash leather.

4—*Physical Properties.*

A slightly yellow transparent crystalline solid, with the odour of Ozone. Fuses at  $44^\circ\text{C}$ . Insoluble in Water.

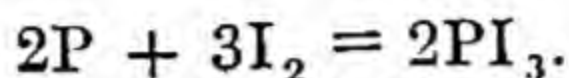




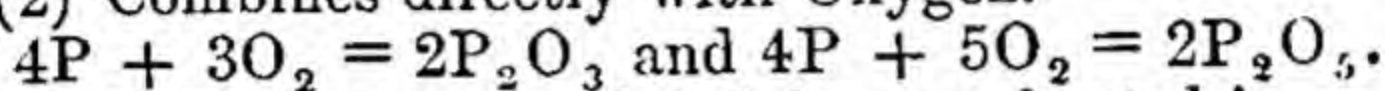
Soluble in Carbon Disulphide, Oils, Fats, and strong Alcohol.

### 5—*Chemical Properties.*

(1) Combines directly with the Halogens evolving heat and light.

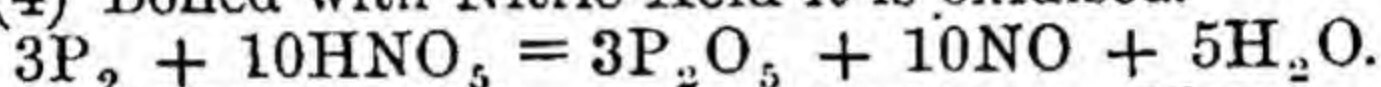


(2) Combines directly with Oxygen.



(3) If Phosphorus and Sulphur are heated in an inert gas (such as Nitrogen) Sulphur and Phosphorus unite to form a yellow liquid,  $P_2S_3$ .

(4) Boiled with Nitric Acid it is oxidised.



(5) Reduces Gold, Silver, Platinum, Mercury, and Copper from their Salts in solution.

(6) Phosphorescence is probably a Chemical property due to slow oxidation. It does not go on in pure Oxygen. Phosphorescence may be destroyed by the presence of very minute quantities of Olefiant Gas, Naptha, or Turpentine vapour.

### 6—*Allotropic modifications.*

(1) If ordinary Phosphorus be kept in Water, free from Air, but exposed to light, it becomes covered with white pellicle of increasing thickness. This has been termed *white* Phosphorus.

(2) If yellow Phosphorus be heated in an inert gas ( $N$  or  $CO_2$ ) to a temperature not exceeding  $240^\circ C$  it becomes red. If Iodine be added to Phosphorus molten in Carbonic Anhydride gas, the Phosphorus is changed into a red amorphous condition. A small quantity of Iodine accomplishes the conversion of an indefinitely large amount of Phosphorus. This is called Brodie's process.

(3) If Red amorphous Phosphorus be dissolved in Molten Lead, it will separate in small Rhombohedral crystals when the mass cools. The crystals can be isolated by dissolving away the Lead by means of dilute Nitric Acid.



(4) The following table will exhibit the difference between yellow and red Phosphorus :—

Yellow Phosphorus.	Red Phosphorus.
Crystalline.	Amorphous.
Characteristic Odour.	Odourless.
Phosphorescent.	Not Phosphorescent.
Readily fusible.	Infusible.
Density, 1.8.	2.14.
Soluble in CS <sub>2</sub> .	Insoluble in CS <sub>2</sub> .
Readily Oxidised,	Not so readily Oxidised.
Oxidised by HNO <sub>3</sub> .	Not Oxidised by HNO <sub>3</sub> .
Poisonous	Not Poisonous.

(5) If Red Phosphorus be heated beyond 240°C it is converted again to the Crystalline variety.

#### 7—Matches.

*Ordinary* Matches are tipped with a mixture of ordinary Phosphorus and Potassium Chlorate.

*Safety* Matches are tipped with a mixture of Potassium Chlorate, Antimonious Sulphide and powdered Glass. They are inflamed by friction on a paper on the box. This paper is coated with a mixture of *Amorphous* Phosphorus and Powdered glass.

#### 8—Molecular weight.

The molecular weight of Phosphorus is anomalous. The molecule contains four atoms of Phosphorus, each having a relative weight of 31.



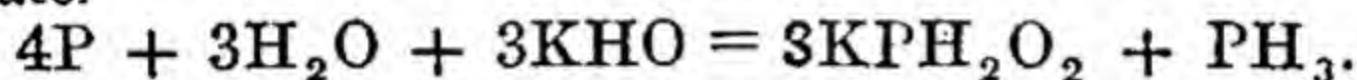


## Compound of Phosphorus and Hydrogen.

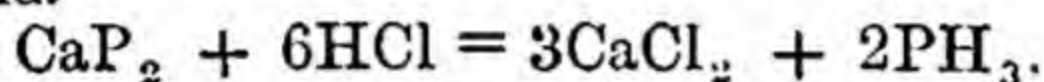
### Phosphuretted Hydrogen, $\text{PH}_3$ .

#### 1—*Preparation.*

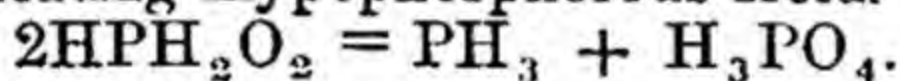
(1) By boiling Phosphorus in a solution of Potassium Hydrate.



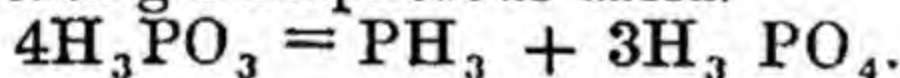
(2) By treating Calcium Phosphide with dilute Hydrochloric Acid.



(3) By heating Hypophosphorous Acid.



(4) By heating Phosphorous Acid.

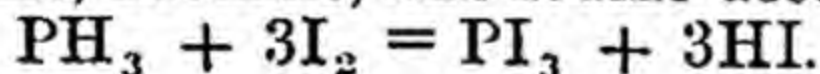


#### 2—*Physical Properties.*

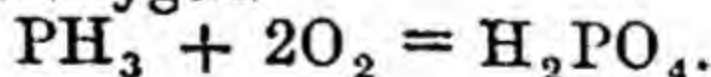
A colourless gas with alliaceous (like onions) odour.

#### 3—*Chemical Properties.*

(1) Chlorine, Bromine, and Iodine decompose it.

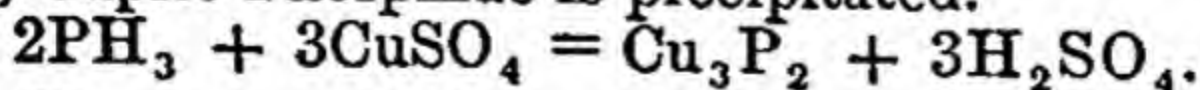


(2) Burns in Oxygen.

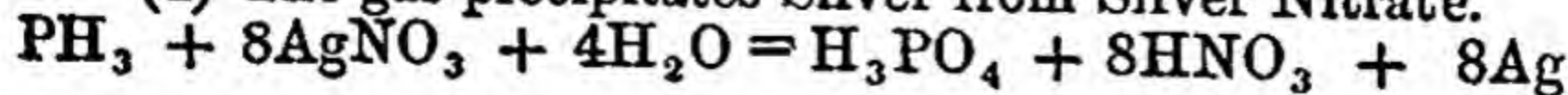


When Phosphuretted Hydrogen is delivered through Water, the bubbles inflame spontaneously when they come in contact with air.

(3) If the gas be passed through a Cupric Salt in solution, Cupric Phosphide is precipitated.



(4) The gas precipitates Silver from Silver Nitrate.







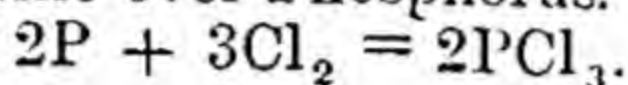
## Compounds of Phosphorus with the Halogens.

Phosphorous Chloride,  $\text{PCl}_3$ .

Phosphoric Chloride,  $\text{PCl}_5$ .

### 1—*Preparation.*

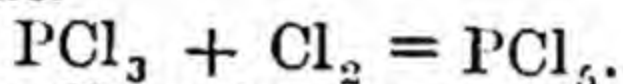
Passing Chlorine over Phosphorus.



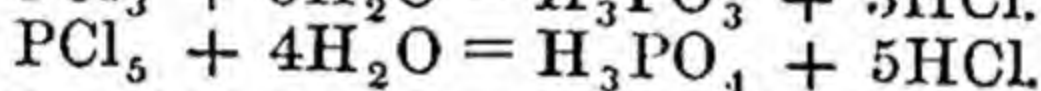
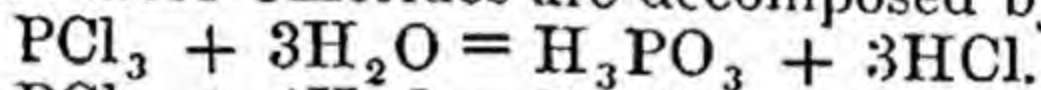
### 2—*Properties.*

(1) A yellow or almost colourless liquid.

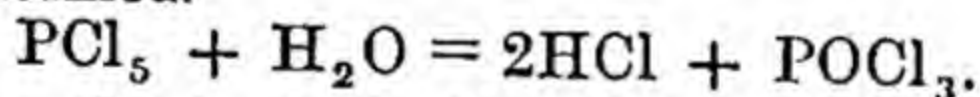
(2) It combines with a molecule of Chlorine, forming Phosphoric Chloride.



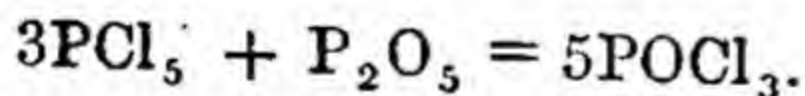
(3) Both these Chlorides are decomposed by Water.



But if the Chloride is in excess of the Water an Oxy-chloride is formed.



(4) Phosphoric Chloride combines with Phosphoric Anhydride.



## The Bromides and Iodides of Phosphorus.

These are best formed by adding Bromine or Iodine to Phosphorus dissolved in Carbon Disulphide. The compounds best known are:— $\text{PBr}_3$ ,  $\text{PBr}_5$ ,  $\text{PI}_3$ . Their reactions are analogous to the reactions of the corresponding Chlorides.



## Compounds of Phosphorus with Oxygen.

Anhydrides.	Acids.
$P_2O_3$ Phosphorus Anhydride	$HPH_2O_2$ Hypophosphorous Acid
$P_2O_5$ Phosphoric Anhydride	$H_3PO_3$ Phosphorous Acid
	$H_3PO_4$ Phosphoric Acid

### Hypophosphorous Acid, $HPH_2O_2$ .

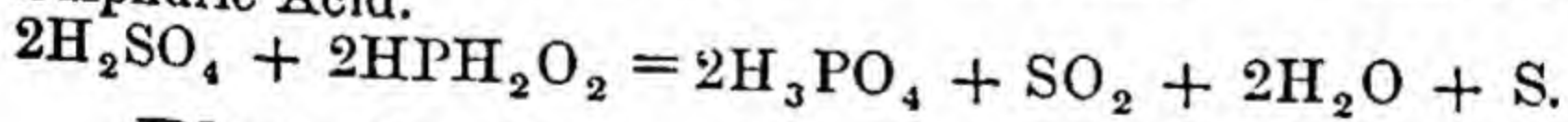
#### 1—*Preparation.*

If Phosphorus be boiled in Calcic Hydrate, a solution of Calcium Hypophosphite,  $Ca(PH_2O_2)_2$ , is obtained.

If this be treated with Sulphuric Acid, Calcium Sulphate will separate, leaving a solution of Hypophosphorous Acid.

#### 2—*Properties.*

A syrupy liquid. Although its molecule contains three atoms of Hydrogen, yet the Acid is monobasic. It reduces Silver and Mercury from their Salts. It reduces Sulphuric Acid.



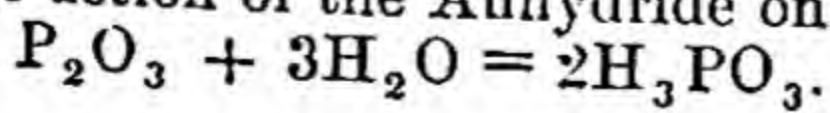
### Phosphorous Anhydride, $P_2O_3$ .

This is a white powder produced by the slow oxidation of Phosphorus in a limited supply of air.

### Phosphorous Acid.

#### 1—*Preparation.*

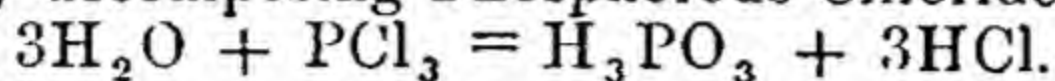
(1) By the action of the Anhydride on Water.







(2) By decomposing Phosphorous Chloride.



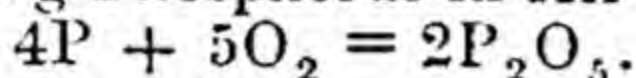
2—*Properties.*

A powerful reducing agent. When heated, it breaks up into Phosphoric Acid and Phosphuretted Hydrogen.

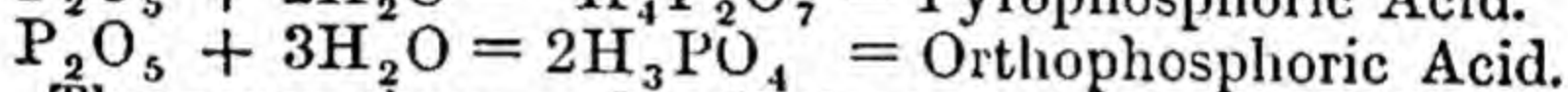
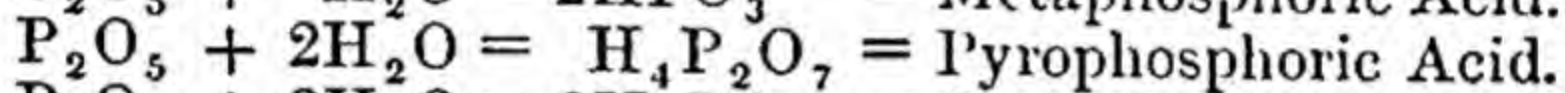
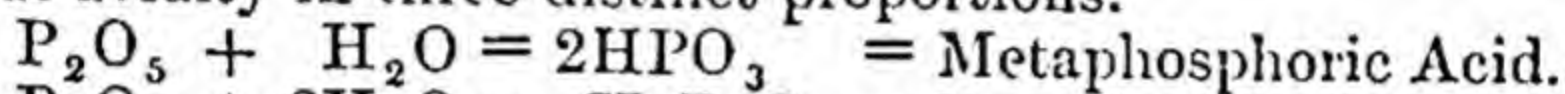
## Phosphoric Anhydride, $\text{P}_2\text{O}_5$ .

1—*Preparation.*

(1) By burning Phosphorus in Air or in Oxygen.



A white powder which combines with Water with great avidity in three distinct proportions.



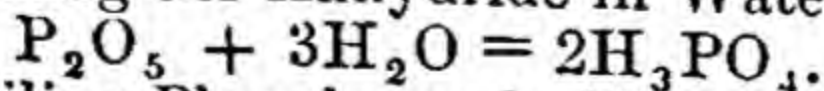
These are three quite distinct Acids with different properties, and not the same Acid in three stages of hydration. The following table will show these differences :

Acids.	Distinctive Tests.	
Metaphosphoric	White ppt with $\text{AgNO}_3$	Coagulates Albumen
Pyrophosphoric	White ppt with $\text{AgNO}_3$	Does not coagulate Albumen
Orthophosphoric	Yellow ppt with $\text{AgNO}_3$	Does not coagulate Albumen

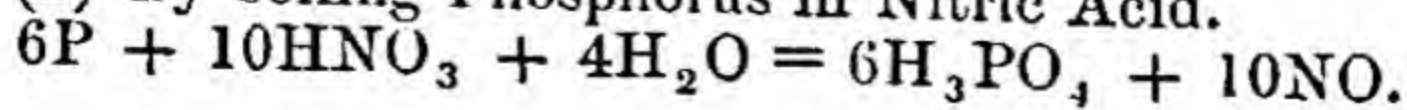
## Orthophosphoric Acid, $\text{H}_3\text{PO}_4$ .

1—*Preparation.*

(1) By boiling the Anhydride in Water.

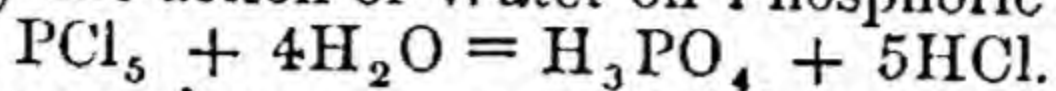


(2) By boiling Phosphorus in Nitric Acid.

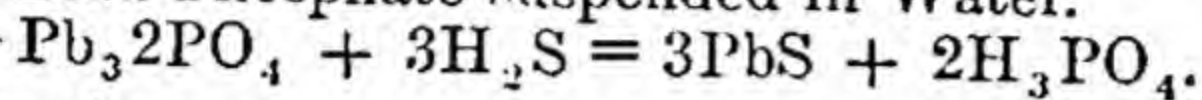




(3) By the action of Water on Phosphoric Chloride.

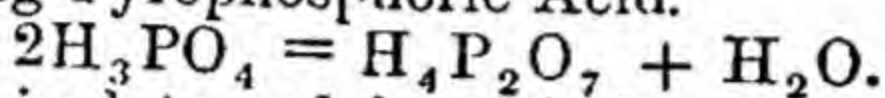


(4) By passing a stream of Sulphuretted Hydrogen through Lead Phosphate suspended in Water.



## 2—*Properties.*

When heated to about  $200^\circ\text{C}$ , it loses one molecule of Water, forming Pyrophosphoric Acid.

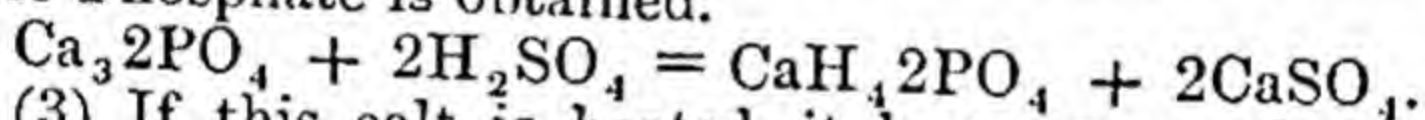


When raised to red heat, it loses two molecules of Water, becoming a molecule of Metaphosphoric Acid. As this body has a glassy appearance, it is called Glacial Phosphoric Acid.

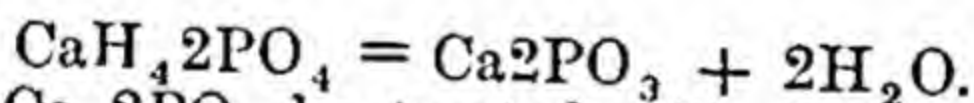
## 3—*Derivatives of Calcic Phosphate.*

(1) Calcic Phosphate,  $\text{Ca}_3\text{2PO}_4$ , is the source of Phosphates.

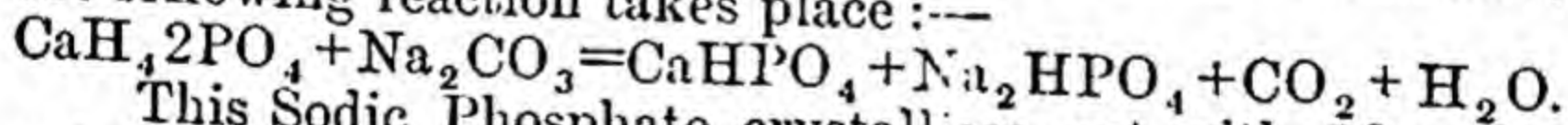
(2) By treating with Sulphuric Acid the Calcic Tetrahydric Phosphate is obtained.



(3) If this salt is heated, it loses two molecules of Water.

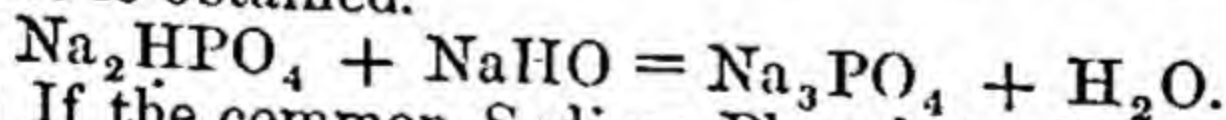


(4) If  $\text{Ca}_3\text{2PO}_4$  be treated with Sodium Carbonate, the following reaction takes place:—

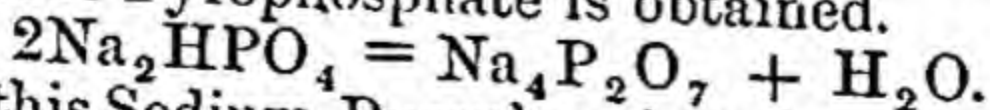


This Sodid Phosphate crystallises out with 12 molecules of Water of crystallisation,  $\text{Na}_2\text{HPO}_4, 12\text{H}_2\text{O}$ .

(5) If Sodium Hydrate be added to this salt, Trisodium Phosphate is obtained.



(6) If the common Sodium Phosphate,  $\text{Na}_2\text{HPO}_4$ , be heated, Sodium Pyrophosphate is obtained.

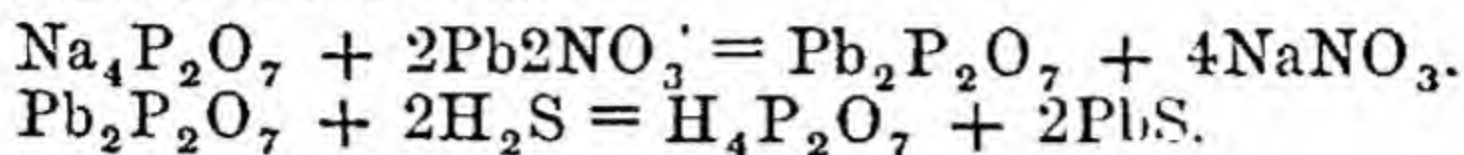


(7) If this Sodium Pyrophosphate be precipitated by a Lead Salt, and a stream of Sulphuretted Hydrogen be

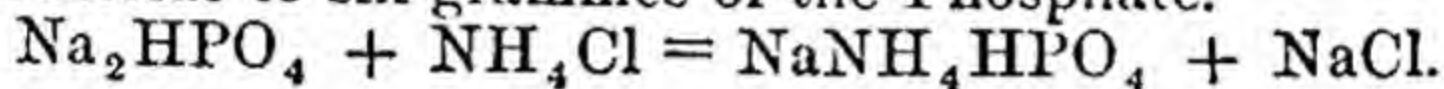




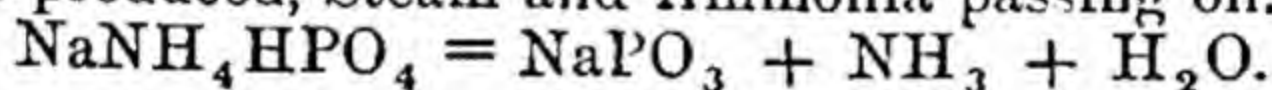
passed through the precipitate in suspension, Pyrophosphoric Acid is obtained.



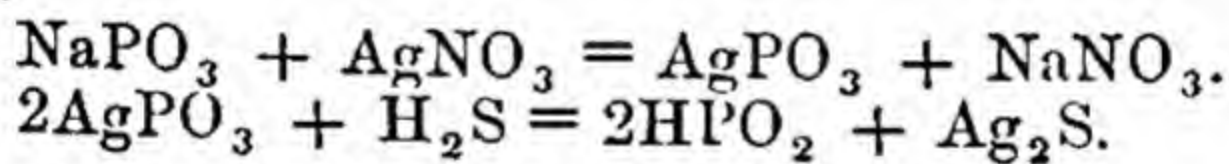
(8) If to the common Sodium Phosphate,  $\text{Na}_2\text{HPO}_4$ , dissolved in hot water, Ammonium Chloride,  $(\text{NH}_4)\text{Cl}$ , be added, Microcosmic Salt crystallises out on cooling. The proportion in which the Ammonium Chloride should be added to the Sodium Phosphate can be calculated from the molecular weights. The proportion is about one gramme of the Chloride to six grammes of the Phosphate.



(9) If Microcosmic Salt be heated, Sodium Metaphosphate is produced, Steam and Ammonia passing off.



(10) If this Sodium Metaphosphate be treated with a Lead or Silver Salt, followed up by a stream of Sulphuretted Hydrogen, Metaphosphoric Acid will be produced in solution.



#### 4—Tests for Orthophosphates.

(1) All insoluble except the Phosphates of the Alkalis.

(2) A yellow precipitate with Silver Nitrate, soluble in Ammonia.

(3) Ammonium Molybdate dissolved in Nitric Acid gives a yellow coloration, and, on heating, a yellow precipitate.

(4) Magnesium Salts in the presence of Ammonium Chloride give a white crystalline precipitate of Ammonio-Magnesium Phosphate.





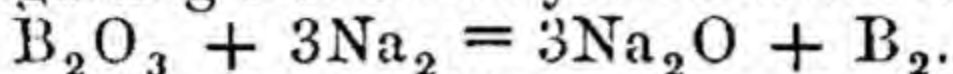
## Boron B, 11.

### 1—*Sources.*

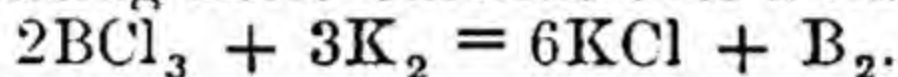
Boric Acid,  $H_3BO_3$ , found in Tuscany, and as an Acid Borate in Tincal which is found in Thibet. Borax is found in California.

### 2—*Preparation.*

(1) By igniting Boric Anhydride with Sodium.



(2) By passing Boric Chloride over Potassium.



### 3—*Physical Properties.*

A brownish amorphous powder, odourless and tasteless, insoluble in Water.

### 4—*Allotropic Modification. Diamond Boron.*

If Boric Anhydride is heated with a metal, such as Sodium, which does not dissolve the Boron which is produced, an amorphous variety of Boron is the product of the reaction. But, if Boric Anhydride be fused with a metal, such as Aluminium, which dissolves Boron, crystals of Boron, almost comparable to the Diamond, crystallise in the Aluminium.

The Aluminium can be removed by Hydrochloric Acid, which is without action on these crystals.

### 5—*Physical Properties of Crystalline Boron.*

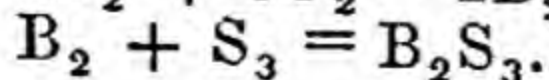
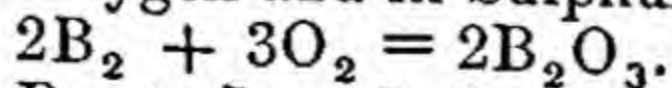
Brilliant crystals of the First system. Density, 2.69. Very hard. Can scratch Corundum. Refractive power almost equal to Diamond. Infusible even in Oxyhydrogen blow-pipe flame.

### 6—*Chemical Properties of Amorphous Boron.*

(1) A gaseous compound with Hydrogen, probably  $BH_3$ , has been discovered.

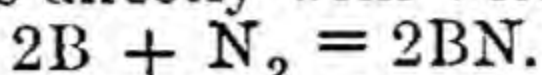
(2) Combines directly with Chlorine and Bromine. Whether with Iodine is doubtful.

(3) Burns in Oxygen and in Sulphur.

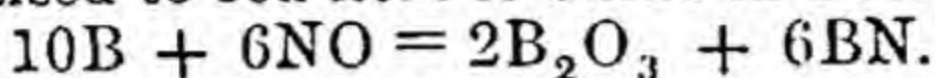




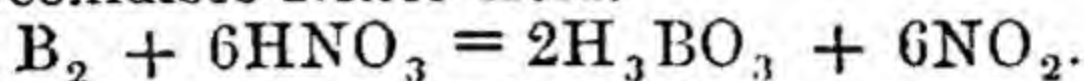
(4) It combines directly with Nitrogen at red heat.



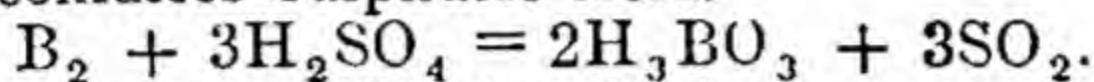
(5) If raised to red heat it burns in Nitric Oxide.



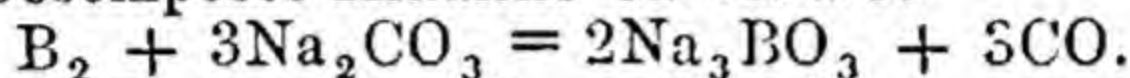
(6) Deoxidises Nitric Acid.



(7) Deoxidises Sulphuric Acid.



(8) Decomposes Alkaline Carbonates.



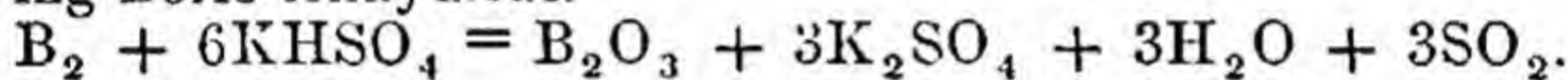
#### 7—*Chemical Properties of Crystalline Boron.*

(1) With great difficulty, and only at the highest temperatures, does it burn in Oxygen.

(2) Burns in Chlorine.

(3) Acids have no action upon it.

(4) Hydrogen Potassium Sulphate acts upon it forming Boric Anhydride.



#### 8—*Atomic weight of Boron.*

(1) In the molecule of the gaseous compounds  $\text{BCl}_3$ ,  $\text{BBr}_3$ , and  $\text{HBF}_4$ , the lowest weight of Boron found is 11 units.

(2) Davy found by analysis that 100 parts of Boric Anhydride contained 32 of Boron and 68 of Oxygen.

The amount of Boron which combines with 8 of Oxygen, which is the equivalent of 1 of Hydrogen, is therefore found by the following proportion:—

$$68 : 32 :: 8 : x = 3.7.$$

(3) By Dulong and Petit's law the atomic weight of Boron is found to be 13.

(4) The result finally arrived at, especially from a consideration of the vapour densities of the Chlorides and Bromides, is that the Atomic weight is 11, and that Boron is a triad. For we see that  $11 \div 3.7 = 3$  nearly.



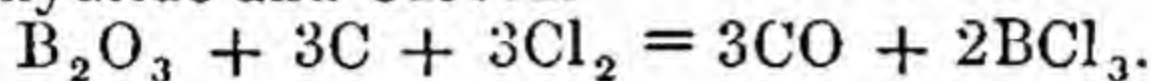


## Boric Chloride, $\text{BCl}_3$ .

### 1—*Preparation.*

(1) By direct union of the elements.

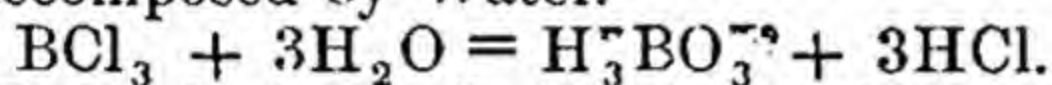
(2) By the action of Chlorine gas upon a mixture of Boric Anhydride and Carbon.



### 2—*Properties.*

A liquid. Its vapour density is 4.065.

It is decomposed by Water.

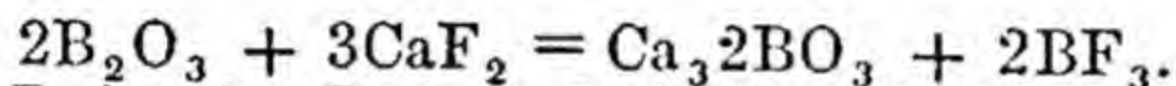


Boric Bromide is similarly obtained and has similar properties.

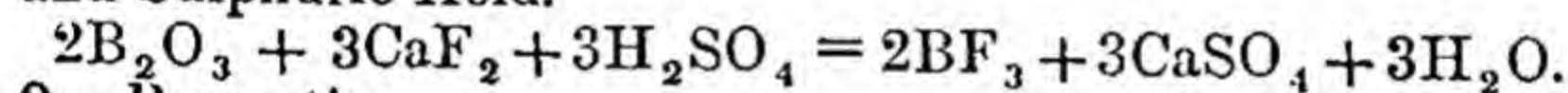
## Boric Fluoride, $\text{BF}_3$ .

### 1—*Preparation.*

(1) By heating Calcium Fluoride with Boric Anhydride.

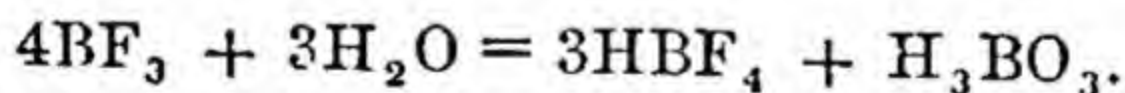


(2) By heating Boric Anhydride with Calcium Fluoride and Sulphuric Acid.



### 2—*Properties.*

A colourless gas with suffocating odour. Density, 2.3126. Decomposed by Water, forming Hydrofluoboric Acid.



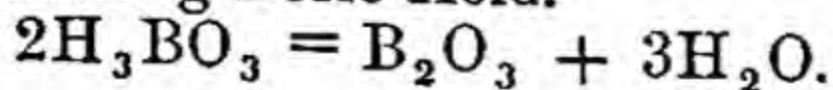
## Compounds of Boron and Oxygen.

### Boric Anhydride, $\text{B}_2\text{O}_3$ .

#### 1—*Preparation.*

(1) By burning Amorphous Boron in Oxygen.

(2) By Calcining Boric Acid.





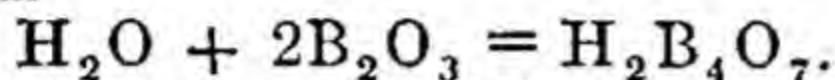
## 2—Physical Properties.

Colourless vitreous, solid. Fusible and volatile at a very high temperature.

## 3—Chemical Properties.

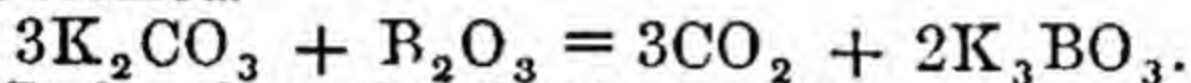
(1) With Water it forms Boric Acid.

(2) If left exposed to moist air it is transformed into Tetraboric Acid.



(3) It dissolves in warm Alkaline solutions.

(4) When heated with Potassium Carbonate, Potassium Borate is formed.



(5) It dissolves the Oxides of many metals, yielding characteristic colours.

Cobalt or Copper	-	yields a blue colour
Iron or Nickel	-	„ red „
Manganese	-	„ violet „
Chromium	-	„ green „

## Boric Acid, $\text{H}_3\text{BO}_3$ .

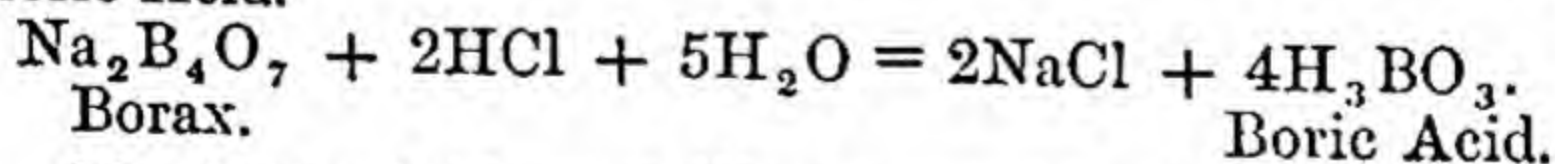
### 1—Source.

The evaporation of natural waters of the Lagoni in Tuscany.

### 2—Preparation.

(1) By Hydrating the Anhydride.

(2) By treating a hot solution of Borax with Hydrochloric Acid.



The Boric Acid crystallises out on cooling.

### 3—Physical Properties.

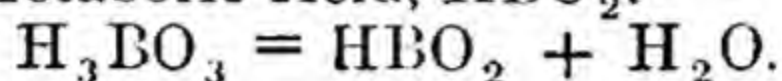
A white solid crystallising in shining nacreous scales. Soluble in Water, and very soluble in alcohol.



#### 4—*Chemical Properties.*

Feebly acid.

(1) At 100°C it loses a molecule of Water, and is converted into Metaboric Acid,  $\text{HBO}_2$ .



(2) Metallic Oxides and Carbonates act on the Acid in the same way as upon the Anhydride.

#### 5—*Tests for Borates.*

(1) Nearly all Borates except Alkaline Borates are insoluble.

(2) Dissolved in alcohol and ignited, a green colour is imparted to flame.

(3) Treated with Hydrochloric Acid they cause moist turmeric paper to become red when it dries.

## The Carbon Group. Carbon and Silicon.

These elements agree in being both tetrads. Each exists in three conditions—the Amorphous, the Graphitoidal, and the Adamantine varieties.

### Carbon, $\text{C}'''$ , 12.

#### 1—*Sources.*

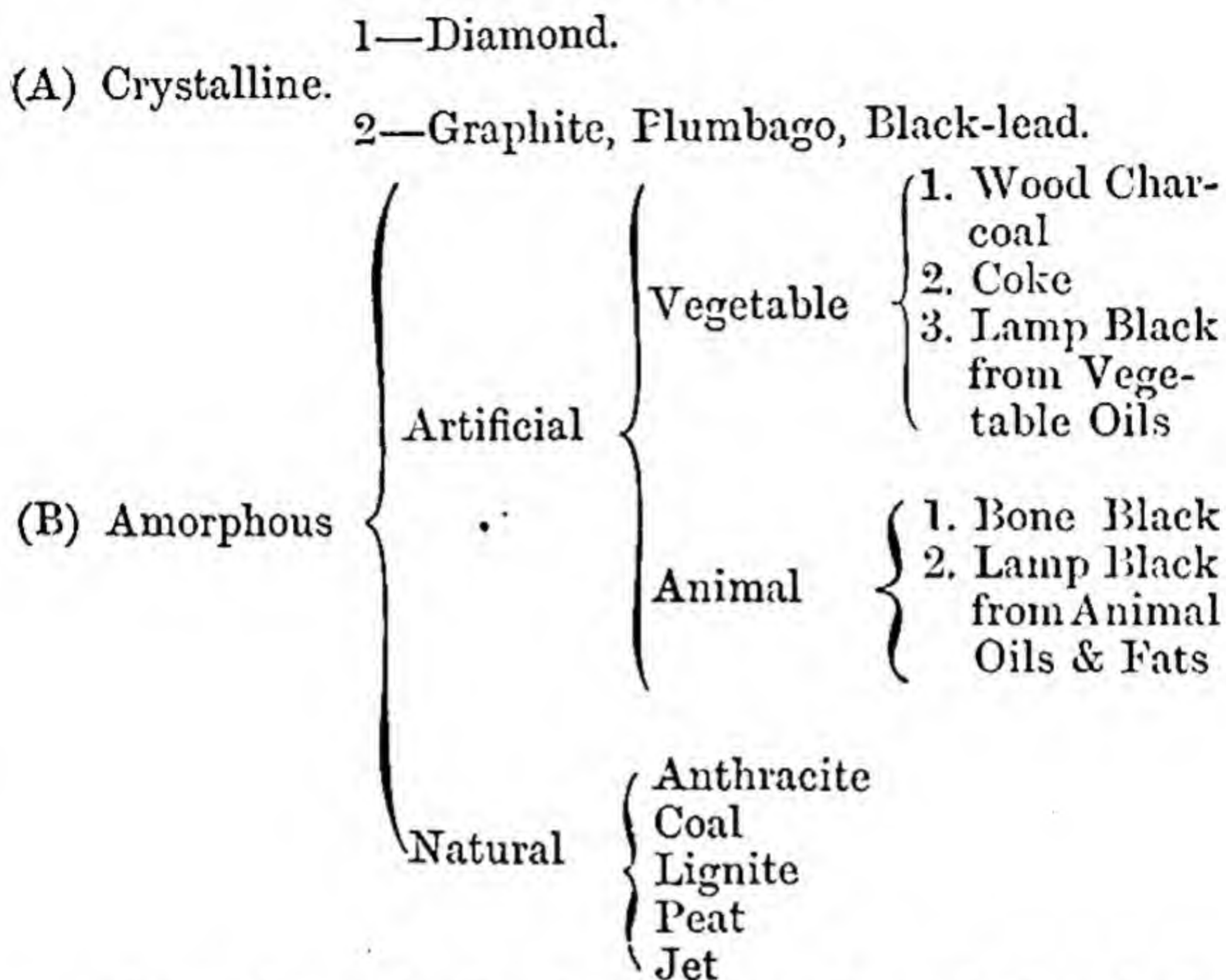
Carbon is an essential element in organic nature. What Carbon is to organised bodies Silicon is to the earth's crust.

#### 2—*Varieties of Carbon.*





## Carbon.



(1)—Diamond. Octohedral Crystals. Hardest body known. Density, 3.5. Non-conductor of heat and electricity. In a strong electric current it is converted into black Carbon. It burns in Oxygen forming Carbon Dioxide.

(2)—Graphite, Plumbago, or Black-lead. Prepared artificially by saturating molten iron with Carbon. Graphite crystallises out. It crystallises in hexagonal plates. It is a good conductor of heat and electricity. Treated with Nitric Acid and Potassic Chlorate, Graphitic Acid,  $\text{CH}_4\text{O}_5$ , is formed.

(3)—Charcoal. Prepared by the destructive distillation of Wood. Very porous. Bad conductor of heat and of electricity. Absorbs gases. An active deodoriser and disinfectant.



(4)—Coke is formed by the destructive distillation of Coal.

(5)—Lamp Black is the sooty deposit of flames. It may be animal, vegetable, or mineral, according as animal, vegetable or mineral oils undergo combustion.

(6)—Bone Black is prepared from bones as Charcoal and Coke are prepared from wood and coal. It contains much Calcium Phosphate. It is a powerful decolouriser.

(7)—Anthracite Coal, Lignite, and Peat are vegetable matter in different stages of carbonisation. Anthracite contains the highest percentage of Carbon and Peat the lowest. In the passage from Peat to Anthracite there is a gradual decrease in the percentage of Oxygen and of Hydrogen, and a corresponding increase in the percentage of Carbon.

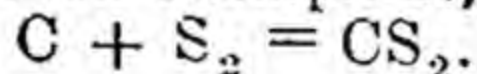
(8)—Carbon is infusible and insoluble in all liquids.

#### 4—*Chemical Properties.*

(1) When an electric arc is made in an atmosphere of Hydrogen, Acetylene,  $C_2H_2$ , is formed.

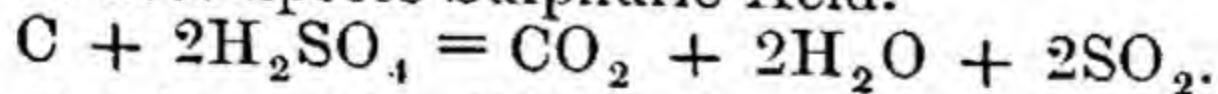
(2) Burns in Oxygen, forming Carbon Dioxide, or if the supply of Oxygen is limited, Carbon Monoxide.

(3) If Sulphur vapour be passed over Charcoal, a heavy oily liquid, Carbon Disulphide, is produced.



(4) It decomposes steam at low red heat, forming  $CO_2$ , and at a higher temperature forming CO.

(5) It decomposes Sulphuric Acid.



(6) It reduces Metallic Oxides, *e.g.*,



(7) Nitrates and Chlorates deflagrate on Charcoal.





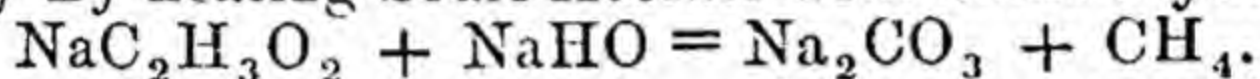
## Compounds of Carbon with Hydrogen.

Methyl Hydride	$\text{CH}_4$ .
Acetylene	$\text{C}_2\text{H}_2$ .
Ethene	$\text{C}_2\text{H}_4$ .

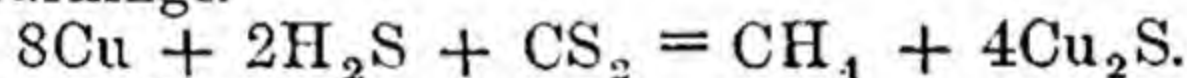
### Methyl Hydride, $\text{CH}_4$ .

#### 1—*Preparation.*

(1) By heating Sodid Acetate with Sodid Hydrate.



(2) By passing a mixture of the vapours of Carbon Disulphide and Sulphuretted Hydrogen over red hot Copper turnings.

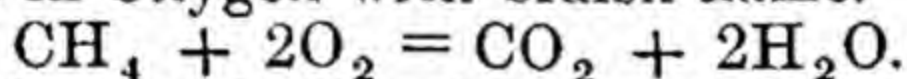


#### 2—*Physical Properties.*

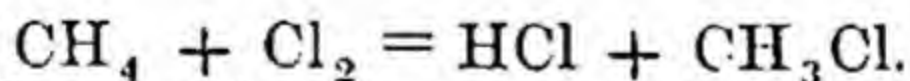
A colourless gas. Found in Coal Mines (Fire-damp), and stagnant Water—called also Marsh Gas, and light Carburetted Hydrogen. Collected over Water.

#### 3—*Chemical Properties.*

(1) Burns in Oxygen with bluish flame.



(2) Combines with Chlorine, forming Methylic Chloride.



#### 4—*Proof of Composition.*

If 100 volumes of Marsh Gas be exploded in a Eudiometer, with 300 of Oxygen, there will remain after the explosion 200 volumes of gas. Of these 200 volumes, 100 volumes are absorbed by Potassium Hydrate. Therefore 100 volumes are Carbonic Acid. The remaining 100 are found to be Oxygen.

Now, 100 volumes of Carbonic Acid contain 100 volumes of Oxygen.



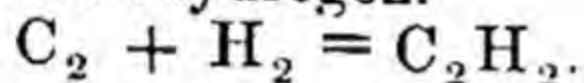
Therefore, another 100 volumes of Oxygen have combined with Hydrogen. The amount of this Hydrogen must be 200 volumes.

100 vols. of Marsh Gas contain	200 vols. of Hydrogen
and . . . 2 vols.                    „                    contain	4 vols. of Hydrogen
. . . 22.4 litres of Marsh Gas weighing	16 grammes
contain 44.8 litres of Hydrogen weighing	4 grammes

Therefore the Carbon in 22.4 litres weighs 12 grammes, which is the relative weight of the atom of Carbon. The formula, is, therefore,  $\text{CH}_4$ .

### Acetylene, $\text{C}_2\text{H}_2$ .

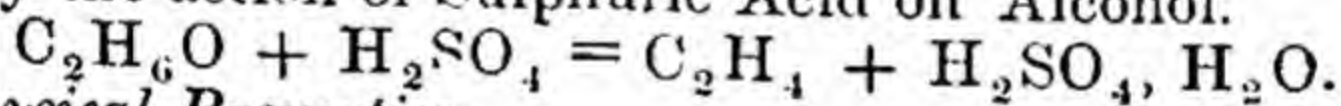
This body is found when the electric arc is made between Carbon terminals in Hydrogen. Carbon combines directly with the Hydrogen.



### Ethene, $\text{C}_2\text{H}_4$ .

#### 1—*Preparation.*

By the action of Sulphuric Acid on Alcohol.

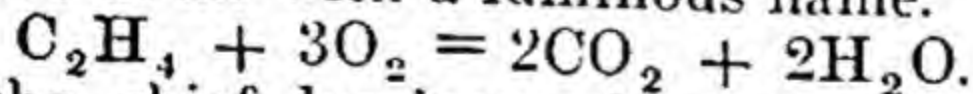


#### 2—*Physical Properties.*

A colourless gas with ethereal odour. Scarcely soluble in Water. Density, .970. Called also Olefiant Gas, and Heavy Carburetted Hydrogen,

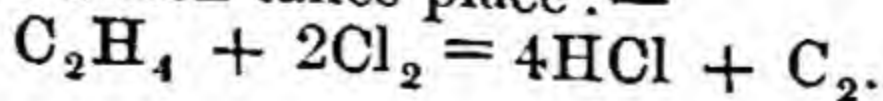
#### 3—*Chemical Properties.*

(1) Burns in air with a luminous flame.



It is the chief luminous ingredient in Coal Gas, though forming only about 5 per cent of it.

(2) If one volume of this gas be mixed with two volumes of Chlorine, on the application of a lighted taper the following reaction takes place:—







(3) If equal volumes of Chlorine and Ethene be exposed to light, a heavy oily liquid is formed, having the composition,  $C_2H_4Cl_2$ , Dutch Liquid.

#### 4—*Proof of Composition.*

After exploding 100 vols of this gas with 400 of Oxygen, 300 vols. of gas remain.

Potassium Hydrate absorbs 200 volumes of the 300 volumes. Therefore 200 volumes are Carbonic Acid. The remaining 100 volumes are Oxygen. Now, 200 volumes of Carbonic Acid contain 200 volumes of Oxygen. Therefore, 100 volumes of Oxygen have combined with 200 volumes of Hydrogen. Hence 100 volumes of this gas contain 200 volumes of Hydrogen, or 1 volume of Ethene contains 2 volumes of Hydrogen.

Now, 22.4 litres of Ethene weigh	28 grammes
and 44.8 litres of Hydrogen weigh	4 grammes

Therefore, the Carbon weighs 24 grammes,  
which is twice the relative weight of the atom of Carbon.  
Therefore, two atoms of Carbon are united to 4 atoms of Hydrogen to form the molecule (2 volumes) of Ethene.  
Hence the formula is  $C_2H_4$ .

### Compounds with Oxygen.

Carbonic Anhydride	$CO_2$ .
Carbonic Oxide	$CO$ .

### Carbonic Anhydride, $CO_2$ .

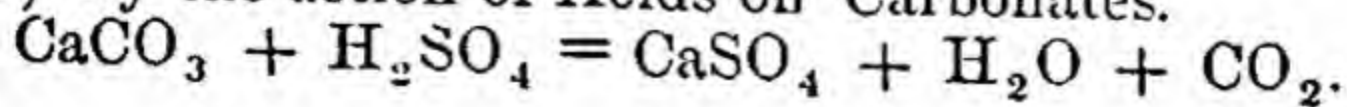
#### 1—*Sources.*

Found in the atmosphere. A constant product of decomposition, respiration, fermentation, and ordinary combustion. Found in many mineral waters.

#### 2—*Preparation.*

(1) By burning Carbon in Oxygen.

(2) By the action of Acids on Carbonates.





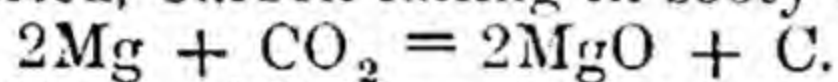


### 3—*Physical Properties.*

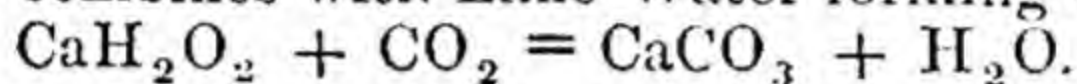
A colourless gas, giving a feebly acid aqueous solution. Its density, 1.53. Collected over Water, or by downward displacement. It can be liquified at  $0^{\circ}$  under a pressure of 36 atmospheres. If, then, a portion of the liquid is allowed to evaporate, a portion always solidifies owing to the great quantity of heat rendered latent in the evaporation. In this liquid state it exhibits no acid properties.

### 4—*Chemical Properties.*

(1) Potassium and Magnesium burn in it. These metals are oxidised, Carbon falling in sooty flakes.



(2) It combines with Lime Water forming Chalk.



### 5—*Proof of Composition.*

(1) Carbon burns in any volume of Oxygen forming the same volume of Carbonic Anhydride.

Thus any volume of Carbonic Anhydride contains its own volume of Oxygen.

Now 22.4 litres of  $\text{CO}_2$  weigh 44 grammes,  
and 22.4 litres of  $\text{O}_2$  weigh 32 grammes,

therefore the Carbon must weigh 12 grammes.

(2) If Oxygen be passed over a known weight of Carbon, and the Carbonic Anhydride produced be collected in Potash tubes, the increase of weight of the Potash tubes will be the weight of the Carbonic Acid produced. The loss of weight of the Carbon taken will be the amount of Carbon in this Carbonic Anhydride. The difference between these two weights is the weight of the Oxygen. So we know the weight of Oxygen and of Carbon in any given weight of Carbonic Anhydride.

### 6—*Tests for Carbonates.*

(1) All are insoluble in Water except the Carbonates of Na, K,  $\text{NH}_4$ .



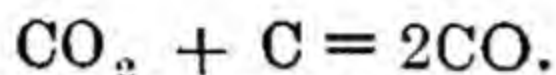
(2) They effervesce and evolve Carbon Dioxide on the addition of an Acid. The gas evolved turns Lime Water milky.

## Carbonic Oxide, CO.

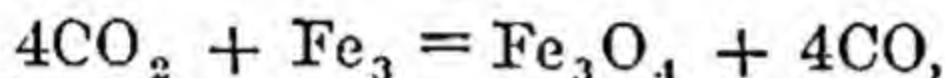
### 1—*Preparation.*

(1) By burning Carbon in a quantity of Oxygen insufficient for complete combustion.

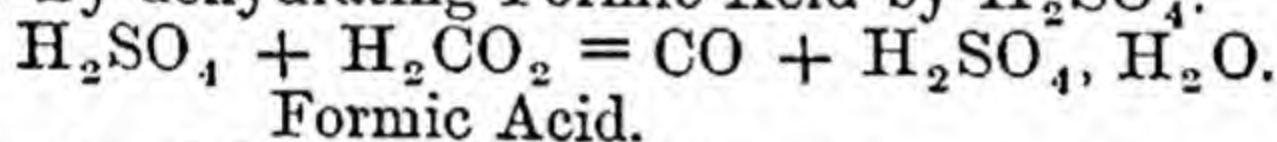
(2) By passing Carbon Dioxide over Carbon at a high temperature.



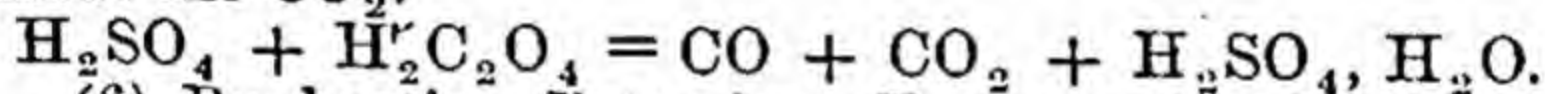
(3) By passing Carbon Dioxide over heated iron filings.



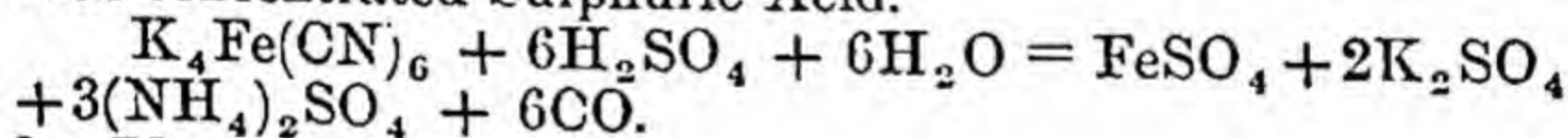
(4) By dehydrating Formic Acid by  $\text{H}_2\text{SO}_4$ .



(5) By dehydrating Oxalic Acid and passing the mixed gaseous products through Lime Water, which absorbs the  $\text{CO}_2$ .



(6) By heating Potassium Ferrocyanide  $\text{K}_4\text{Fe}(\text{CN})_6$  with concentrated Sulphuric Acid.

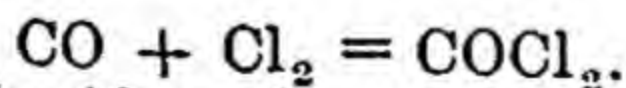


### 2—*Physical Properties.*

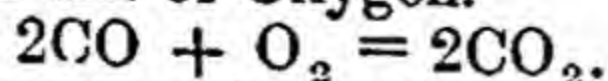
A colourless gas. Poisonous. Density, .9691. Collected over Water.

### 3—*Chemical Properties.*

(1) It combines directly with Chlorine, forming Carbonyl Chlorine.



(2) It burns in Air or Oxygen.



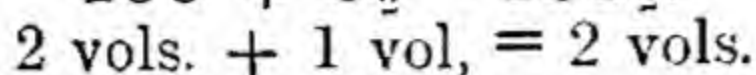
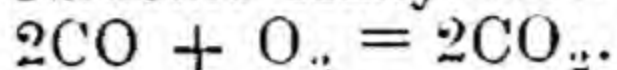
(3) It is an important deoxidising agent in Metallurgy.





4—*Proof of Composition.*

It combines with half its volume of Oxygen, yielding its own volume of Carbonic Anhydride.

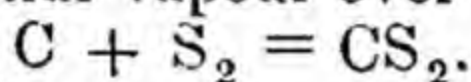


Now Carbonic Anhydride contains its own volume of Oxygen, therefore Carbonic Oxide must contain half its own volume of Oxygen.

Hence if the formula for Carbonic Anhydride is  $\text{CO}_2$ , the formula for Carbonic Oxide must be  $\text{CO}$ .

Carbon Disulphide,  $\text{CS}_2$ .1—*Preparation.*

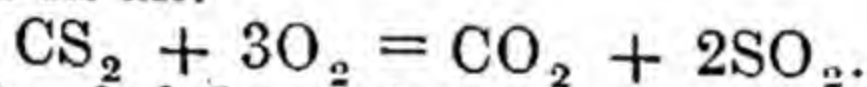
By passing Sulphur vapour over red hot Charcoal.

2—*Physical Properties.*

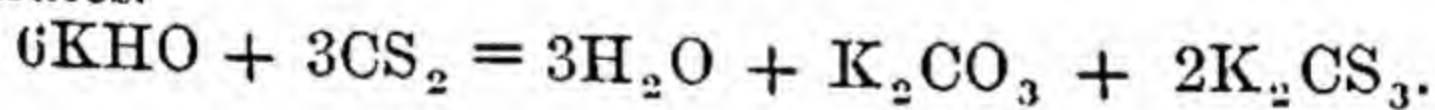
A colourless mobile liquid with strong, unpleasant odour. Extremely volatile, producing great cold by evaporation. Dissolves Phosphorus, Caoutchouc, Sulphur.

3—*Chemical Properties.*

(1) Burns in air.



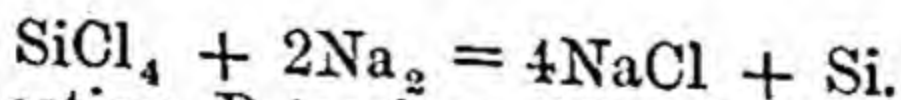
(2) Yields Sulpho-carbonates when treated with Hydrates.

Silicon,  $\text{Si}'''$  28.1—*Sources.*

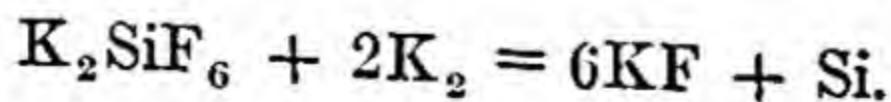
Quartz, Flint, Sinter.

2—*Preparation.*

(1) By passing the vapour of Silicon Chloride over Sodium.



(2) By heating Potassium Silicofluoride with Potassium.





### 3—*Physical Properties.*

Exists in three allotropic forms. Amorphous, Graphitoidal, and Adamantine.

(1) Amorphous. Prepared as above. Silicon is a brown amorphous powder, which conducts heat and electricity badly. It readily burns in air or Oxygen, forming  $\text{SiO}_2$ .

(2) Graphitoidal. If Amorphous Silicon be fused in Aluminium, or if Potassium Silicofluoride be heated to  $1100^\circ\text{C}$  with Aluminium, and the product heated with  $\text{HCl}$ , the Aluminium is dissolved out and Silicon is left in shining hexagonal scales, which may be compared to graphite. Graphitoidal Silicon is a good conductor of heat and of electricity.

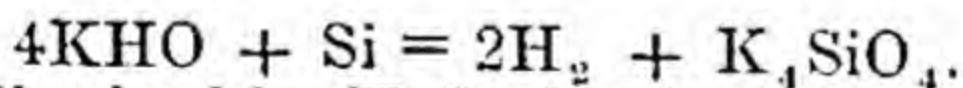
(3) Adamantine. If Aluminium be heated strongly in a current of Silicon Chloride, Aluminium Chloride is formed, and immediately volatilises, leaving Adamantine Silicon. The crystals are octohedral, and of an iron grey colour. They are not nearly so hard as the crystalline Boron and Carbon.

### 4—*Chemical Properties.*

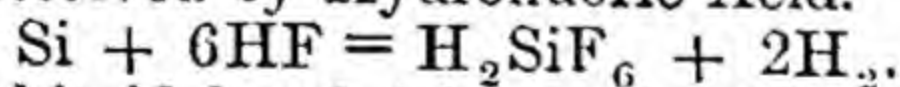
(1) Combines directly with Chlorine, forming  $\text{SiCl}_4$ .

(2) Burns in Oxygen forming  $\text{SiO}_2$ .

(3) Boiled in Potassic Hydrate, it yields Potassium Silicate.



(4) Is dissolved by Hydrofluoric Acid.

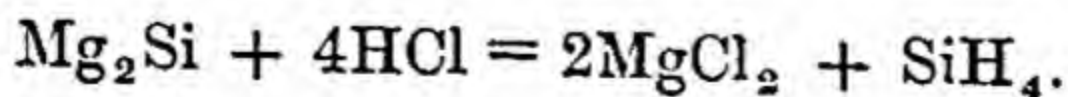


(5) Graphitoidal and Adamantine Silicon are attacked by a mixture of Nitric and Hydrofluoric Acids.

## Silicon Hydride, $\text{SiH}_4$ .

### 1—*Preparation.*

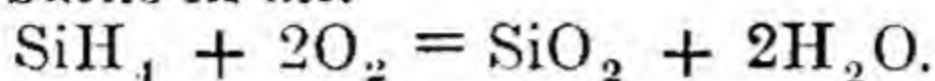
By decomposing Magnesium Silicide with Hydrochloric Acid.





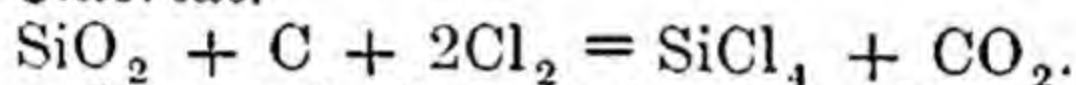
2—*Properties.*

A colourless transparent gas. In the presence of Hydrogen it burns in air.

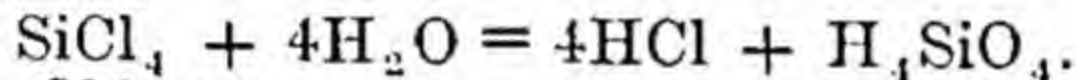


## Compounds of Silicon with the Halogens.

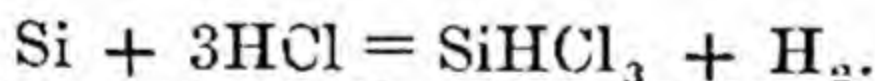
Silicon Chloride	$\text{SiCl}_4$ .
Silicon Chloroform	$\text{SiHCl}_3$ .
Silicon Bromide	$\text{SiBr}_4$ .
Silicon Iodide	$\text{SiI}_4$ .
Silicon Fluoride	$\text{SiF}_4$ .

1—*Silicon Chloride.*

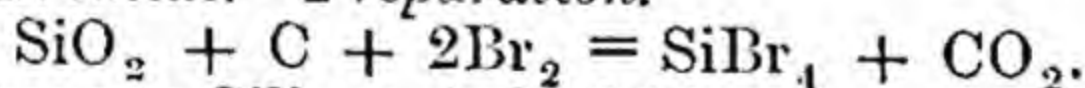
A colourless, volatile, fuming liquid, readily decomposed by Water.

2—*Silicon Chloroform.*

Prepared by heating crystalline Silicon in Hydrochloric gas.



A colourless, volatile liquid. Readily transformed by Chlorine into  $\text{SiCl}_4$ , and by Bromine into  $\text{SiBrCl}_3$ .

3—*Silicon Bromide. Preparation.*

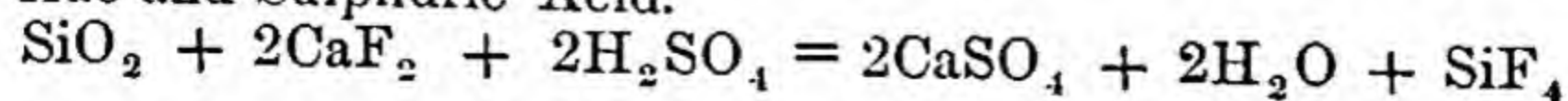
Analogous to Silicon Anhydride.

4—*Silicon Iodide.*

Prepared by passing Iodine Vapour with Carbonic Anhydride over heated Silicon. Silicon Iodide not being very stable it must be distilled in some such inert gas as Carbonic Anhydride.

5—*Silicon Fluoride. (1) Preparation.*

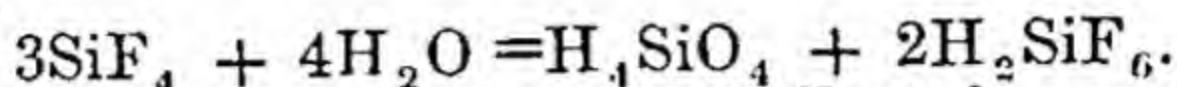
By heating together a mixture of Sand, Calcium Fluoride and Sulphuric Acid.







(2) Excess of Sulphuric Acid is always employed in order that the Water produced in the reaction may be retained, and so prevented from decomposing the Silicon Fluoride.



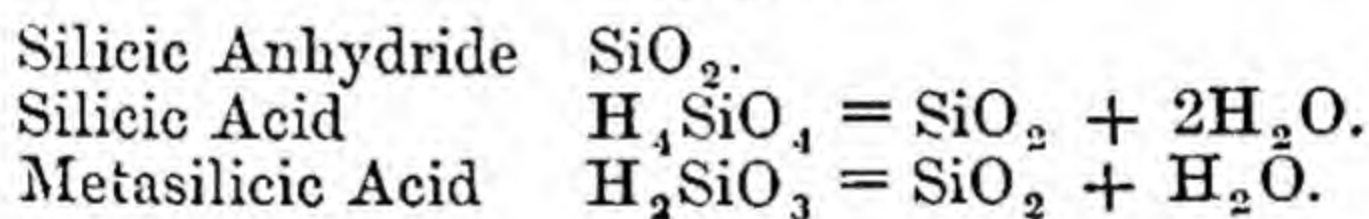
Silicon Fluoride is, therefore, collected over Mercury. Silicon Fluoride has no action on glass.

## Hydrofluosilicic Acid, $\text{H}_2\text{SiF}_6$ .

### *Preparation.*

When Silicon Fluoride is allowed to pass into Water through Mercury, Silica is precipitated, and Hydrofluosilicic Acid remains in solution. Its Potassium Salt is used for the preparation of Silicon.

## Compounds of Silicon with Oxygen.



## Silicic Anhydride, $\text{SiO}_2$ .

### 1—*Sources.*

Quartz, Flint, Sand.

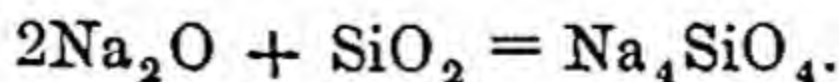
### 2—*Preparation.*

By burning Silicon in Oxygen.

## Silicic Acid, $\text{H}_4\text{SiO}_4$ .

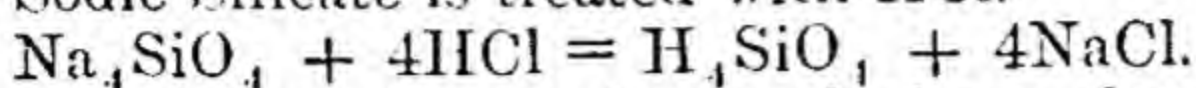
### 1—*Preparation.*

From Flint, &c.—(A) Quartz, Flint, or Sand is fused with Soda.



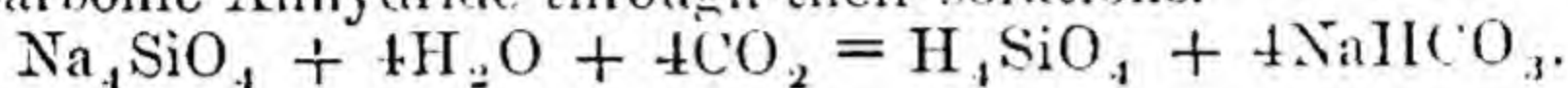


(B) Sodie Silicate is treated with HCl.



Silicic Acid remains partly in solution and partly precipitated.

(2) From soluble Silicates by passing a current of Carbonic Anhydride through their solutions.



### Metasilicic Acid, $\text{H}_2\text{SiO}_3$ .

Prepared by evaporating in vacuo Silicic Acid, it loses one molecule of Water.

#### *Tests for Silicates.*

(1) All Silicates, except Silicates of the Alkalis, are insoluble.

(2) Soluble Silicates give a white gelatinous precipitate with Hydrochloric Acid.

#### *Atomic weight of Silicon.*

(1) It is found that 100 grammes of Silicon combine with 114.3 grammes of Oxygen to form  $\text{SiO}_2$ . The quantity of Silicon that is combined with 32 of Oxygen is therefore 28.

(2) If we subtract the weight of four atoms of Hydrogen, Chlorine, Bromine, or Fluorine from the weight of 22.4 litres of each of the Halogen compounds of Silicon, the remainder in each case will be 28. The least weight of Silicon found in any of its compounds is 28 parts, therefore 28 is taken to be the atomic weight of Silicon.





# QUESTIONS.

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*Prudens quæstio quasi dimidium scientiæ.*

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1.—What are the elements in Clay, Chalk, Flint, Dolomite?

2.—Contrast the results of heating Magnesium ribbon and Platinum wire respectively in Air.

3.—How does Brass differ from Copper? Is Brass a Chemical Compound?

4.—Sulphuric Acid turns blue litmus red, and Potassium Hydrate turns red litmus blue; and it is only when they are mixed in one definite and constant proportion that we obtain a body that effects neither. Why is this?

5.—Given finely powdered Sulphur and finely divided Copper. Shew the difference between Chemical combination and mechanical mixture.

6.—Give an example of Chemical combination when both bodies are solid.

7.—Describe experiments shewing that change in colour, odour, and physical state accompany Chemical action.

8.—Can every element unite with every other element?

9.—Explain how cohesion agrees with and differs from Chemical combination.

10.—When common Salt is dissolved in pure water does any Chemical change take place? How can the Salt be recovered?

11.—When "Sherbet" is dissolved in water Chemical action ensues. How does water act in this case. Can the "Sherbet" be recovered?

12.—What becomes of a candle when it is burnt? What has become of a ton of coal when it has burnt away?

13.—What practical applications do you know of the effects of light in promoting Chemical change?

14.—A piece of Phosphorus, not lighted, is put (1) into Oxygen, (2) into Chlorine. What is observed? Why is it necessary to light a fire?

15.—After a fire is lighted why does it continue to burn?

16.—If a piece of cold Copper is placed in a flame the flame does not touch it. Why?

17.—A can of Coffee can be boiled in a heap of quick lime being slaked. Explain.

18.—When gas was first introduced into houses, nervous people insisted on having the pipes fixed well away from wood-work. Why was this an unnecessary precaution?

19.—Why does a mixture of gas and air explode instead of burning quietly? Why does the gas at a jet burn quietly?

20.—The dust-laden air of flour-mills has been known to explode. Explain this.

21.—What precautions are taken to avoid explosions in mines?

22.—How is it proved that the Thermal change that accompanies Chemical action is *definite* in amount?

23.—Give two examples of each of the "Modes of Chemical Action," stating the conditions of the experiment.

24.—Ammonia Gas and Air are separately shaken up over water. Contrast the results.

25.—When Mercuric Oxide is heated, it turns black. Is this a Chemical change. Explain.

26.—What experiments shew that in Chemical action no matter is lost? Is energy gained or lost?

27.—Describe experiments shewing that Physical State modifies Chemical change.



28.—What takes place when Mercury is heated nearly to its boiling point? What takes place when the temperature is further increased beyond the boiling point?

29.—Describe an experiment shewing combustion in the nascent state.

30.—Give some instances of Catalytic action.

31.—A ton of Caustic Soda from one manufacturer does work which requires 1.25 tons of Caustic Soda from another manufacturer to do. What conclusion do you draw?

32.—From the percentage composition of the oxides of Copper, given on page 9, shew how the Law of Multiple Proportion holds good.

33.—Two compounds of Nitrogen have the following per centage composition :—

$$(1) \begin{array}{l} \text{N} = 63.64 \\ \text{O} = 36.36 \end{array} \} = 100 \qquad (2) \begin{array}{l} \text{N} = 36.84 \\ \text{O} = 63.16 \end{array} \} = 100$$

Find the percentage composition of the compound which is intermediate between them.

34.—A magnet covered with iron filings is on from one end of balance, and duly counterpoised. The filings are heated. What changes take place?

35.—How is it shewn that one gas acts as a vacuum to another?

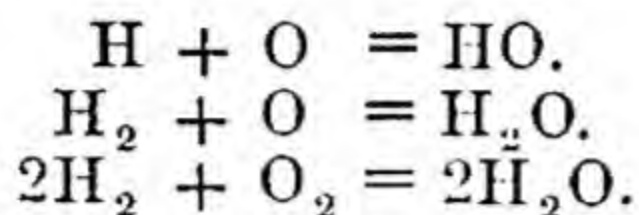
36.—What did Dalton assume when he said that the combining weight of Nitrogen was 4.67?

37.—When we say the Atomic weight of Nitrogen is 14, what is our unit?

38.—Distinguish between the terms Hypothesis, Theory, Law, and give an example of each.

39.—What conclusion is deduced from the fact that all gases expand alike?

40.—What facts are involved in each of the following equations :—



41.—Define the term "Molecule." How does a molecule differ from an atom?

42.—A gas is 35.5 times heavier than Hydrogen, what is its molecular weight?

43.—A gas is 2.5 times heavier than air. Find its molecular weight.

44.—A gas is half as heavy as air. Find its molecular weight.

45.—The molecular weight of Oxygen is 32, find its density compared with air.

46.—The molecular weight of Carbon Dioxide is 44. Find its density compared with air.

47.—What experiments shew that equal weights of different bodies have different capacities for heat? How did Dulong and Petit modify these experiments, and with what results?

48.—Define Specific heat, Atomic heat, and Molecular heat

49.—The Specific heat of Magnesium is .25. Find its atomic weight.

50.—The Atomic weight of Tin is 118. Find its Specific heat.

51.—Explain the terms Amorphous, Dimorphous, Polymorphous, Isomorphous, with examples.

52.—In the table on page 29, the two elements are present in Nitric Peroxide in the ratio of 7 is to 16. Why is not 7 taken as the Atomic weight of Nitrogen?



53.—Describe experiments shewing how the equivalents of Lead and of Magnesium are determined. Find their Specific heats in the table, deduce therefrom their Atomic weights, and then shew how these are related to the equivalents.

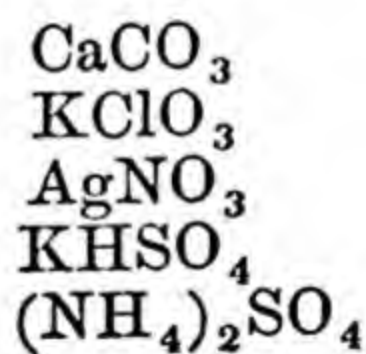
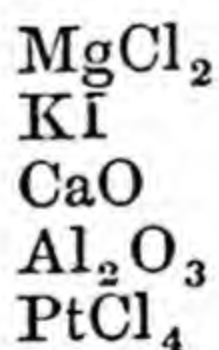
54.—Why are the compounds in sec. 4, page 35 said to be characteristic?

55.—Define the terms Valency and Equivalent, and exemplify each.

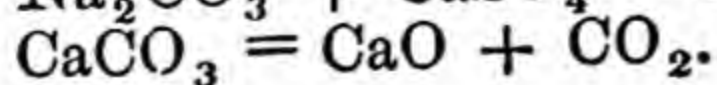
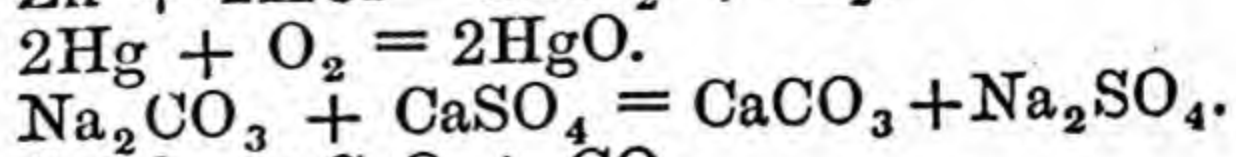
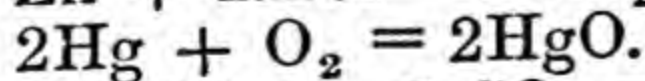
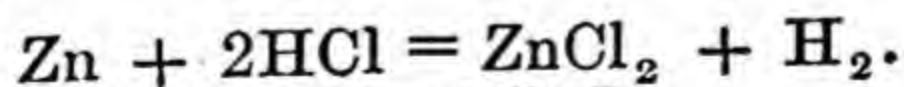
56.—How do we know that the molecule of Mercury contains only one atom, while the molecule of Phosphorus contains four atoms?

57.—Write down the formulæ of the following compounds:— (1) Barium Iodide, (2) Lead Sulphide, (3) Stannic Chloride, (4) Calcium Chlorate, (5) Sodium Carbonate, (6) Copper Sulphate, (7) Lead Nitrate, (8) Barium Phosphate, (8) Manganese Chloride, (10) Magnesium Hydrate.

58.—Write down the names of the bodies that have the following formulæ:—



59.—Give in words the meaning of the following equations:



60.—Define the following terms :— Radicle, Oxide, Alkali, Acid, Anhydride, Basic Oxide, Salt, Hydrate.

61.—What do you understand by the term Base ? Give examples of some Bases.

62.—Find the weight of 50 litres of Chlorine at  $0^{\circ}\text{C}$  and 760mm.

63.—Find the volume of 10 grammes of Ammonia gas at  $0^{\circ}\text{C}$  and 760mm.

64.—Find the weight of 10 litres of Phosphorus Vapour at  $0^{\circ}\text{C}$  and 760mm.

65.—Find the weight of 60 litres of Nitric Oxide at  $0^{\circ}\text{C}$  and 760mm.

66.—If 500 cc of gas be measured at  $10^{\circ}\text{C}$ , what volume will the gas occupy at  $25^{\circ}\text{C}$ ?

67.—500 litres of Oxygen are measured at  $16^{\circ}\text{C}$ . What will the gas measure and weigh at  $0^{\circ}\text{C}$ ?

68.—20 litres of gas are measured at a pressure of 750mm. What will be the volume of the gas at 760mm?

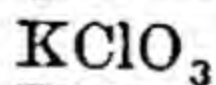
69.—40 litres of Oxygen are collected at a pressure of 770mm. What will the volume of the gas be at 760mm?

70.—If 50 litres of a gas be measured at  $45^{\circ}\text{C}$  and 730mm, what will the gas occupy at  $0^{\circ}\text{C}$  and 760mm?

71.—44 litres of Oxygen are measured at  $50^{\circ}\text{C}$  and 770mm. Find the volume and weight of the Oxygen at  $0^{\circ}\text{C}$  and 760mm.

72.—Calculate the percentage composition of :—

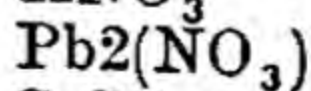
Potassium Chlorate



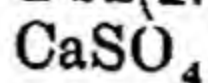
Nitric Acid



Lead Nitrate



Calcium Sulphate



73.—Find formulæ for bodies which have the following percentage composition :—

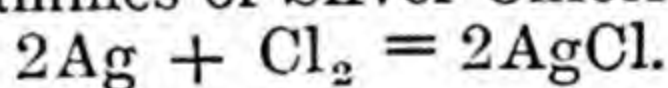
$$\begin{array}{rcl} \text{(1) Nitrogen} & = & 82.35 \\ \text{Hydrogen} & = & 17.65 \\ \hline & & 100. \\ \hline \end{array}$$

$$\begin{array}{rcl} \text{(2) Iron} & = & 70.01 \\ \text{Oxygen} & = & 29.99 \\ \hline & & 100. \\ \hline \end{array}$$

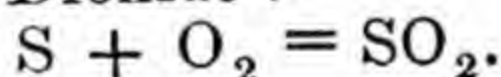
$$\begin{array}{rcl} \text{(3) Potassium} & = & 28.73 \\ \text{Hydrogen} & = & .73 \\ \text{Sulphur} & = & 23.52 \\ \text{Oxygen} & = & 47.02 \\ \hline & & 100. \\ \hline \end{array}$$

$$\begin{array}{rcl} \text{(4) Sodium} & = & 32.79 \\ \text{Aluminium} & = & 13.02 \\ \text{Fluorine} & = & 54.19 \\ \hline & & 100. \\ \hline \end{array}$$

74.—How many litres of Chlorine at  $0^{\circ}\text{C}$  and 760mm will produce 5 grammes of Silver Chloride ?

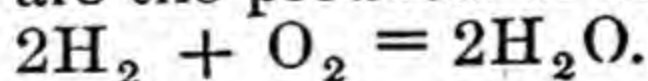


75.—What weight of Oxygen is required to burn 10 grammes of Sulphur Dioxide ?



76.—What volume of Carbonic Acid can be obtained by heating Chalk with 10 grammes of Hydrochloric Acid ?

77.—15 litres of Hydrogen are exploded with 7 litres of Oxygen. What are the products of combustion ?



78.—How are the Metallic Elements classified to aid detection ?

79.—Write down a few of the Elements, and arrange them according to Valency.

80.—What are the Chemical differences between a Metal and a Non-metal ?

81.—Shew in what respects the so-called Metalloids partake of the character both of Metals and of Non-metals.



82.—What are the physical differences between the Metals and the Non-metals?

83.—Discuss the proper position of Hydrogen in classification of Elements, according to all their properties taken together.

84.—Classify the Non-metals, stating the general characters of each group.

85.—Draw diagrams shewing the apparatus for preparing Oxygen, and by four distinct methods.

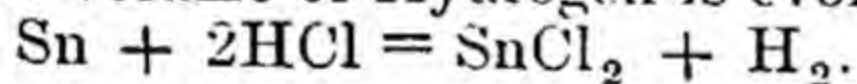
86.—What is meant by a crith?

87.—A litre of Oxygen is said to weigh 16 criths. What do you mean by that?

88.—Find, in terms of the crith, the weight of a litre of (1) Chlorine, (2) Hydrochloric Acid, HCl.

89.—How many litres of Hydrogen can be obtained by the action of 4 grammes of Magnesium wire on dilute Sulphuric Acid?

90.—If 5 grammes of Tin are boiled in Hydrochloric Acid, what volume of Hydrogen is evolved?



91.—At what pressure and temperature does the 5 grammes of Tin produce this volume of Hydrogen? Suppose the temperature  $15^\circ\text{C}$ , and the pressure 750mm, what would the volume be?

92.—Define and exemplify the terms Allotropism and Isomerism.

93.—Describe six experiments shewing the Chemical properties of the Halogens, stating accurately the conditions of each experiment.

94.—Draw the apparatus for preparing Chlorine.

95.—Draw the apparatus for making Hydrochloric Acid.

96.—How do you collect gaseous Hydrochloric Acid, and demonstrate its extreme solubility?

97.—Draw Hoffmann's apparatus for decomposing Hydrochloric Acid. How does it differ from the similar apparatus used for decomposing Water?

98.—Describe accurately the experiment from which you infer the composition of Hydrochloric Acid.

99.—Seeing that Fluorine has never been isolated, how do we know its Atomic weight?

100.—How could you etch your name on your watch glass?

101.—How many grammes of Iodine are liberated from Potassium Iodide by the Chlorine evolved by the action of 8.68 grammes of Manganese Dioxide on Hydrochloric Acid?

102.—How did Priestley discover Oxygen?

103.—How did Lavoisier utilize the above discovery?

104.—What physical change takes place when Potassium Chlorate is heated? Can this change be prevented?

105.—Draw the apparatus by which you saw Oxygen made.

106.—Why is the delivery tube taken out of the pneumatic trough before the lamp is removed?

107.—Under what conditions does Iron rust?

108.—Why are steel goods often packed in Lime?

109.—A piece of Sodium and a piece of Phosphorus are separately burnt in Oxygen. Contrast the Chemical characters of the products.

110.—What is Graham's Law of Diffusion of gases? If 8 litres of Ozone diffuse through an apparatus in the same time that 4 litres of Hydrogen diffuse under similar conditions, find the density of Ozone compared with Hydrogen.



111.—Two elements combine together in the following proportions:—

96.28 : 3.72.

92.83 : 7.17.

89.62 : 10.38.

86.62 : 13.38.

From these numbers deduce Dalton's Law of Multiple Proportion.

112.—Describe Soret's experiments to determine the formula of Ozone.

113.—When Chlorine mixed with Oxygen diffused through a small aperture into Oxygen the proportion of diffused Chlorine to that remaining in the vessel in 45 minutes was represented by the number .227. While in a similar experiment made with Ozonised Oxygen, the proportion of diffused Oxygen to that remaining in the vessel in 45 minutes was .2708.

From these numbers determine the density of Ozone.  
(1) with Chlorine as unity; (2) with Hydrogen as unity.

114.—How do you show that when Hydrogen is burnt Water is produced?

115.—Sketch the apparatus for showing the composition of Water by weight.

116.—How can Oxygen be prepared from Water?

117.—When 52.821 grammes of Copper Oxide were heated in contact with Hydrogen, the residual Copper weighed 42.689 grammes, and 12.197 grammes of Water were obtained. Find the percentage composition of Water.

118.—When 11.2 litres of Hydrogen are passed over 180 grammes of Copper Oxide, what weight of Water is produced?

119.—How do you collect and weigh the Water in the above experiment?

120.—Describe Clark's process for estimating the hardness of Water.

121.—Compare the heating power of a jet of Hydrogen burning in Air and in Oxygen. Explain the difference.

122.—(1) Hydrogen is bubbled through a solution of Ferric Chloride. (2) Ferric Chloride is added to the bottle in which Hydrogen is being generated. State what takes place in each case. Define the term "Nascent State."

123.—By what experiments can you show that Sulphur is Dimorphous?

124.—Describe what takes place when Sulphur is heated. If a piece of Copper wire be immersed in the vapour what takes place?

125.—Describe the experiment by which Hydrogen and Sulphur are made to combine directly.

126.—Sketch the apparatus for preparing Hydrogen Sulphide from (1) Ferrous Sulphide, (2) Antimony Sulphide.

127.—Sketch the apparatus for preparing Sulphur Dioxide from Copper and Sulphuric Acid. Why does the Copper turn black?

128.—By what arrangement is Sulphur Dioxide condensed? What tests distinguish Sulphates from Sulphites?

129.—Describe the action of Sulphurous Acid on a solution of Iodine.

130.—Sketch the apparatus for showing this preparation of Sulphuric Acid on the small scale, and describe the chemistry of the process.

131.—Describe how Ammonia is produced synthetically.

132.—By what experiment is the extreme solubility of Ammonia in Water demonstrated?

133.—Compare the action of a solution of Ammonia in Water with the action of Sodium Hydrate on the following: (1) Hydrochloric Acid, (2) Red Litmus, (3) Ferric Sulphate.



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